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A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Intermontane Prairie Pothole Wetlands in the Northern Rocky Mountains

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Environmental Laboratory

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Assessing Wetland Functions

A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Intermontane Prairie Pothole Wetlands in the Northern Rocky Mountains (ERDC/EL TR-02-7)

ISSUE: Section 404 of the Clean Water Act directs the U.S. Army Corps of Engineers to administer a regulatory program for permitting the discharge of dredged or fill material in "waters of the United States." As part of the permit review process, the impact of discharging dredged or fill material on wetland functions must be assessed. On 16 August 1996 a National Action Plan to Implement the Hydrogeomorphic Approach (NAP) for developing Regional Guidebooks to assess wetland functions was published. This report is one of a series of Regional Guidebooks that will be published in accordance with the National Action Plan.

RESEARCH OBJECTIVE: The objective of this research was to develop a Regional Guidebook for assessing the functions of intermontane prairie pothole wetlands in the northern Rocky Mountains in the context of the 404 Regulatory Program.

SUMMARY: The Hydrogeomorphic (HGM) Approach is a collection of concepts and methods for developing functional indices and subsequently using them to assess the capacity of a wetland to perform functions relative to similar wetlands in a region. The approach was initially designed to be used in the context of the Clean Water Act Section 404 Regulatory Program permit review sequence to consider alternatives, minimize impacts, assess unavoidable project impacts, determine mitigation requirements, and monitor the success of mitigation projects. However, a variety of other potential applications for the approach have been identified, including: determining minimal effects under the Food Security Act, designing mitigation projects, and managing wetlands. This report uses the HGM Approach to develop a Regional Guidebook for assessing the functions of intermontane prairie pothole wetlands in the northern Rocky Mountains.

AVAILABILITY OF REPORT: The report is available at the following Web site: *http://www.wes.army.mil/el/wetlands/wlpubs.html.* The report is also available on Interlibrary Loan Service from the U.S. Army Engineer Research and Development Center (ERDC) Research Library, telephone (601) 634-2355, or the following Web site: *http://libweb.wes.army.mil/index.htm.*

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Preface

This Regional Guidebook was authorized by Headquarters, U.S. Army Corps of Engineers (HQUSACE), as part of the Characterization and Restoration of Wetlands Research Program (CRWRP). It is published as an Operational Draft for field testing for a 2-year period. Comments should be submitted via the Internet at the following address: *http://www.wes.army.mil/el/wetlands/hgmhp.html*. Written comments should be addressed to Department of the Army, Research and Development Center, CEERD-EE-W, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199.

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The report was prepared by Dr. F. Richard Hauer and Mr. Bradley J. Cook, Flathead Lake Biological Station, University of Montana, Polson, MT; Mr. Michael C. Gilbert, U.S. Army Engineer District, Omaha; and Dr. Clairain and Mr. R. Daniel Smith, Wetlands and Coastal Ecology Branch (WCEB), Ecosystem Evaluation and Engineering Division, EL. This work took place under the general supervision of Dr. Morris Mauney, Jr., Chief, WCEB; Dr. David J. Tazik, Chief, Ecosystem Evaluation and Engineering Division; and Dr. Edwin A. Theriot, Director, EL.

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1 Introduction to the Hydrogeomorphic (HGM) Approach

Introduction

The Hydrogeomorphic (HGM) Approach is a collection of concepts and methods that are used to develop and apply functional indices to the assessment of wetlands. The approach was initially designed for use in the Clean Water Act Section 404 Regulatory Program including permit review to consider alternatives, minimize impacts, assess unavoidable project impacts, determine mitigation requirements, and monitor the success of mitigation projects. However, a variety of other potential applications for the approach have been identified: determining minimal effects under the Food Security Act, designing mitigation projects, managing wetlands, and long-term monitoring of wetlands.

On August 16, 1996, a National Action Plan (NAP) to Implement the Hydrogeomorphic Approach was published in the *Federal Register* (National Interagency Implementation Team 1996). The NAP was developed cooperatively by the U.S. Army Corps of Engineers (USACE), U.S. Environmental Protection Agency (USEPA), Natural Resources Conservation Service (NRCS), Federal Highway Administration (FHWA), and U.S. Fish and Wildlife Service (USFWS). Publication of the NAP was designed to outline a strategy and promote the development of Regional Guidebooks for assessing the functions of regional wetland subclasses using the HGM Approach; solicit the cooperation and participation of Federal, State, and local agencies, academia, and the private sector in this effort; and update the status of Regional Guidebook development.

This document is a Regional Guidebook for Intermontane Prairie Pothole Wetlands in the Northern Rocky Mountains. This guidebook provides all the information needed to conduct HGM Functional Assessments for this wetland subclass and includes (a) the rationale for selecting the wetland subclass, (b) characterization of the wetland subclass, (c) the rationale for selecting the functions to be assessed (d) the rationale used to develop the assessment models and select model variables, (e) the selection of specific metrics as indicators of wetland function, (f) the data from reference wetlands used to calibrate the model

variables, and (g) the necessary protocols for applying the functional indices to the assessment of wetland functions.

Organization, Background, and Content

The document is organized into six chapters plus four appendixes. Chapter 1 outlines the organization of the report. Chapter 2 introduces the HGM developmental history, provides a brief overview of the major components of the HGM Approach, and discusses the Development and Application Phases required to implement the approach. Chapter 3 characterizes the geographical extent, climate, geomorphic setting, hydrology, vegetation, soils, and other factors that influence wetland function in Intermontane Prairie Pothole Wetlands in the Northern Rocky Mountains. Chapter 4 discusses each wetland function, model variable, and functional index. Chapter 5 provides the protocols necessary to conduct an assessment using office data, field methods for completing metric-specific field data forms, and use of computing procedures in the office to calculate Functional Capacity Indices for each function of a project wetland. The References (Chapter 6) follow the main text. Appendix A presents a Glossary of terms used in this report. Appendix B summarizes wetland functions and variables. Appendix C contains the Field Data Sheets, and Appendix D contains the Reference Wetland Data Set.

Software to compute Functional Capacity Indices is available at *http://www.wes.army.mil/el/wetlands/hgmhp.html.*

2 Overview of the Hydrogeomorphic Approach

The HGM Approach to Wetland Functional Assessment is a collection of concepts and methods that are used to develop and apply functional indices to the assessment of wetlands. The HGM Approach includes four integral components: (a) HGM Classification, (b) Reference Wetlands, (c) Assessment Models and Functional Indices, and (d) Application Protocols. The four components of the HGM Approach are integrated into a Regional, Subclass-specific Guidebook such as this document. In the Development Phase of the HGM Approach, research scientists and regulatory managers work cooperatively to select a list of functions and indicators of function that will best represent the functional range of variation among wetlands of the subclass and region. An Assessment Team (A-Team) gathers data from an array of wetlands that represent that range of variation and establish a data set of Reference Wetlands. The functional models and data are combined along with field protocols and methods for analysis to formulate the Regional Guidebook. The end users then employ the Regional Guidebook during the Application Phase to conduct HGM functional assessments on project wetlands. Each of these components of the HGM Approach is discussed briefly in this chapter. More extensive discussions of these topics can be found in Brinson (1993, 1995a, 1995b), Brinson et al. (1995, 1996, 1998), Clairain (2002), Davis (in preparation, Chapter 5, Chapter 8), Hauer and Smith (1998), Smith (2001, in preparation), Smith and Wakeley (2001), Smith et al. (1995), and Wakeley and Smith (2001).

Hydrogeomorphic Classification

Wetland ecosystems share a number of characteristics including relatively long periods of inundation or saturation, hydrophytic vegetation, and hydric soils. In spite of these shared characteristics they occur under a wide range of climatic, geologic, and physiographic situations, and exhibit a wide variety of physical, chemical, and biological characteristics (Cowardin et al. 1979; Ferren, Fiedler, and Leidy 1996; Ferren et al. 1996a, 1996b; Mitsch and Gosselink 1993; Semeniuk and Semeniuk 1995). This variability presents a challenge to the development of assessment methods that are both accurate, in the sense that the

method detects significant change in function, and practical, in the sense the method can be carried out in the relatively short time frame that is generally available for conducting assessments. "Generic" methods, designed to assess multiple wetland types, lack the resolution necessary to detect significant changes in function. Consequently, one way to achieve an appropriate level of resolution within the available time frame is to reduce the level of variability exhibited by the wetlands being considered (Smith et al. 1995).

The HGM Classification was developed specifically to accomplish this task (Brinson 1993). It identifies groups of wetlands that function similarly using three criteria that fundamentally influence how wetlands function: geomorphic setting, water source, and hydrodynamics. Geomorphic setting refers to the landform and position of the wetland in the landscape. Water source refers to the primary source of the water in the wetland such as precipitation, overbank floodwater, or groundwater. Hydrodynamics refers to the level of energy and the direction that water moves in the wetland.

Based on these three criteria, any number of "functional" wetland groups can be identified at different spatial or temporal scales. For example, at a continental scale, Brinson (1993) identified five hydrogeomorphic wetland classes. These were later expanded to the seven classes described by Smith et al. 1995 (Table 1).

In many cases, the level of variability in wetlands encompassed by a continental scale hydrogeomorphic class is still too great to develop assessment models that can be rapidly applied while being sensitive enough to detect changes in function at a level of resolution appropriate to the 404 review process. For example, at a continental geographic scale the depression class includes wetlands as diverse as California vernal pools (Zedler 1987), prairie potholes in North and South Dakota (Kantrud, Krapu and Swanson 1989; Hubbard 1988), playa lakes in the High Plains of Texas (Bolen, Smith, and Schramm 1989), kettles in New England, and cypress domes in Florida (Kurz and Wagner 1953; Ewel and Odum 1984).

To reduce both inter- and intra-regional variability the three classification criteria are applied at a smaller, regional geographic scale to identify regional wetland subclasses. In many parts of the country, existing wetland classifications can serve as a starting point for identifying these regional subclasses (Ferren, Fiedler, and Leidy 1996; Ferren et al. 1996a, 1996b; Golet and Larson 1974; Stewart and Kantrud 1971; Wharton et al. 1982). Regional subclasses, like the continental classes, are distinguished on the basis of geomorphic setting, water source, and hydrodynamics. In addition, certain ecosystem or landscape characteristics may also be useful for distinguishing subclasses in certain regions. For example, depression subclasses might be based on water source (i.e., groundwater versus surface water) or the degree of connection between the wetland and other surface waters (i.e., the flow of surface water in or out of the depression through defined channels). Tidal fringe subclasses might be based on salinity gradients (Shafer and Yozzo 1998). Slope subclasses might be based on the degree of slope, landscape position, the source of water (i.e., throughflow versus groundwater), or other factors. Riverine subclasses might be based on water source, position in the watershed, stream order, watershed size, channel

Table 1 Hydrogeomorphic Wetland Classes at a Continental Geographic Scale	
HGM Wetland Class	**Definition**
Depression	Depression wetlands occur in topographic depressions (i.e., closed elevation contours) that allow the accumulation of surface water. Depression wetlands may have any combination of inlets and outlets or may be closed basins that lack them completely. Water may come from one or any combination of the following: precipitation, overland flow, streams, or groundwater/interflow from adjacent uplands. The predominant direction of flow is from the higher elevations toward the center of the depression but may come from deep aquifer, subsurface springs. The predominant hydrodynamics are vertical fluctuations that range from diurnal to seasonal. Depression wetlands may lose water as evapotranspiration, through intermittent or perennial outlets, or as recharge to groundwater. Prairie potholes, playa lakes, vernal pools, and cypress domes are common examples of depression wetlands.
Tidal Fringe	Tidal fringe wetlands occur along coasts and estuaries and are under the influence of sea level. They intergrade landward with riverine wetlands where tidal current diminishes and riverflow becomes the dominant water source. Additional water sources may be groundwater discharge and precipitation. The interface between the tidal fringe and riverine classes is where bidirectional flows from tides dominate over unidirectional ones controlled by floodplain slope of riverine wetlands. Because tidal fringe wetlands frequently flood and water table elevations are controlled mainly by sea surface elevation, tidal fringe wetlands seldom dry for significant periods. They lose water by tidal exchange, by overland flow to tidal creek channels, and by evapotranspiration. Organic matter normally accumulates in higher elevation marsh areas where flooding is less frequent and the wetlands are isolated from shoreline wave erosion by intervening areas of low marsh. *Spartina alterniflora* salt marshes are a common example of tidal fringe wetlands.
Lacustrine Fringe	Lacustrine fringe wetlands are adjacent to lakes where the water elevation of the lake maintains the water table in the wetland. In some cases, these wetlands consist of a floating mat attached to land. Additional sources of water are precipitation and groundwater discharge, the latter dominating where lacustrine fringe wetlands intergrade with uplands or slope wetlands. Surface water flow is bidirectional, usually controlled by water-level fluctuations resulting from wind or seiche. Lacustrine wetlands lose water by flow returning to the lake after flooding and evapotranspiration. Organic matter may accumulate in areas sufficiently protected from shoreline wave erosion. Unimpounded marshes bordering the Great Lakes are an example of lacustrine fringe wetlands.
Slope	Slope wetlands are found in association with the discharge of groundwater to the land surface, or at sites with saturated overland flow with no channel formation. They normally occur on sloping land ranging from very gentle to steep. The predominant source of water is groundwater or interflow discharging to the land surface. Direct precipitation is often a secondary contributing source of water. Hydrodynamics are dominated by downslope unidirectional water flow. Slope wetlands can occur in nearly flat landscapes if groundwater discharge is a dominant source to the wetland surface. They lose water primarily by saturated subsurface flows, surface flows, and by evapotranspiration. Slope wetlands may develop channels, but the channels serve only to convey water away from the slope wetland. Slope wetlands are distinguished from depression wetlands by the lack of a closed topographic depression and the predominance of the groundwater/interflow water source. Fens are a common example of slope wetlands.
Mineral Soil Flats	Mineral soil flats are most common on interfluves, extensive relic lake bottoms, or large floodplain terraces where the main source of water is precipitation. They receive virtually no groundwater discharge, which distinguishes them from depressions and slopes. Dominant hydrodynamics are vertical fluctuations. Mineral soil flats lose water by evapotranspiration, overland flow, and seepage to underlying groundwater. They are distinguished from flat upland areas by their poor vertical drainage because of impermeable layers (e.g., hardpans), slow lateral drainage, and low hydraulic gradients. Mineral soil flats that accumulate peat can eventually become organic soil flats. They typically occur in relatively humid climates. Pine flatwoods with hydric soils are a common example of mineral soil flat wetlands.
	(Continued)

Table 1 (Concluded)

HGM Wetland Class	Definition
Organic Soil Flats	Organic soil flats, or extensive peatlands, differ from mineral soil flats, in part because their elevation and topography are controlled by vertical accretion of organic matter. They occur commonly on flat interfluves but may also be located where depressions have become filled with peat to form a relatively large flat surface. Water source is dominated by precipitation, while water loss is by overland flow and seepage to underlying groundwater. They occur in relatively humid climates. Raised bogs share many of these characteristics, but they may be considered a separate class because of their convex upward form and distinct edaphic conditions for plants. Portions of the Everglades and northern Minnesota peatlands are common examples of organic soil flat wetlands.
Riverine	Riverine wetlands occur in floodplains and riparian corridors in association with stream channels. Dominant water sources are overbank flow from the channel or subsurface hydraulic connections between the stream channel and wetlands. Additional water sources may be interflow or occasional overland flow from adjacent uplands, tributary inflow, and precipitation. When overbank flow occurs, surface flows down the floodplain may dominate hydrodynamics. In the headwaters, riverine wetlands often intergrade with slope or depressional wetlands as the channel (bed) and bank disappear, or they may intergrade with poorly drained flats or uplands. Perennial flow is not required. Riverine wetlands lose surface water via the return of floodwater to the channel after flooding and through surface flow to the channel during rainfall events. They lose subsurface water by discharge to the channel, movement to deeper groundwater (for losing streams), and evapotranspiration. Peat may accumulate in off-channel depressions (oxbows) that have become isolated from riverine processes and subjected to long periods of saturation from groundwater sources. Bottomland hardwood floodplains are a common example of riverine wetlands.

gradient, or floodplain width. Examples of potential regional subclasses are shown in Table 2 and in Smith et al. (1995), and Rheinhardt, Brinson, and Farley (1997).

Table 2
Potential Regional Wetland Subclasses in Relation to Geomorphic Setting, Dominant Water Source, and Hydrodynamics

Geomorphic Setting	Dominant Water Source	Dominant Hydrodynamics	Potential Regional Wetland Subclasses	
			Eastern USA	Western USA/Alaska
Depression	Groundwater or interflow	Vertical	Prairie pothole marshes, Carolina bays	California vernal pools
Fringe (tidal)	Ocean	Bidirectional, horizontal	Chesapeake Bay and Gulf of Mexico tidal marshes	San Francisco Bay marshes
Fringe (lacustrine)	Lake	Bidirectional, horizontal	Great Lakes marshes	Flathead Lake marshes
Slope	Groundwater	Unidirectional, horizontal	Fens	Avalanche chutes
Flat (mineral soil)	Precipitation	Vertical	Wet pine flatwoods	Large playas
Flat (organic soil)	Precipitation	Vertical	Peat bogs; portions of Everglades	Peatlands over permafrost
Riverine	Overbank flow from channels	Unidirectional, horizontal	Bottomland hardwood forests	Riparian wetlands

Regional Guidebooks include a thorough characterization of the regional wetland subclass in terms of its geomorphic setting, water sources, hydrodynamics, vegetation, soil, and other features that were taken into consideration during the classification process.

Reference Wetlands

Reference wetlands are the wetland sites selected to represent the range of variability that occurs in a regional wetland subclass as a result of natural processes and disturbance (e.g., succession, channel migration, fire, erosion, and sedimentation) as well as human alteration. The reference domain is the geographic area occupied by the reference wetlands (Smith et al. 1995). Ideally, the geographic extent of the reference domain will mirror the geographic area encompassed by the regional wetland subclass; however, this is not always the case because of time and resource constraints. Reference wetlands serve several purposes. First, they establish a basis for defining what constitutes a characteristic, sustainable level of function across the suite of functions selected for a regional wetland subclass. Second, they establish the range and variability of conditions exhibited by model variables. Third, they provide the data necessary for calibrating model variables and assessment models. Finally, they provide a concrete, physical representation of wetland ecosystems that can be repeatedly observed and measured. Reference standard wetlands are the subset of reference wetlands that perform the suite of functions selected for regional subclass at a level that is characteristic in the least altered wetland sites in the least altered landscapes. Table 3 outlines the terms used by the HGM Approach in the context of reference wetlands.

Table 3
Reference Wetland Terms and Definitions

Term	Definition
Reference Domain	The geographic area from which reference wetlands representing the regional wetland subclass are selected (Smith et al. 1995).
Reference Wetlands	A group of wetlands that encompass the known range of variability in the regional wetland subclass resulting from natural processes and disturbance and from human alteration.
Reference Standard Wetlands	The subset of reference wetlands that perform a representative suite of functions at a level that is both sustainable and characteristic of the least-human-altered wetland sites in the least-human-altered landscapes. By definition, all functions in reference standard wetlands are assigned a Functional Capacity Index of 1.0.
Reference Standard Wetland Variable Condition	The range of conditions exhibited by model variables in reference standard wetlands. By definition, reference standard conditions receive a variable subindex score of 1.0.
Site Potential (mitigation project context)	The highest level of function possible given local constraints of disturbance history, land use, or other factors. Site potential may be less than or equal to the levels of function in reference standard wetlands of the regional wetland subclass.
Project Target (mitigation project context)	The level of function identified or negotiated for a restoration or creation project.
Project Standards (mitigation context)	Performance criteria and/or specifications used to guide the restoration or creation activities toward the project target. Project standards should specify reasonable contingency measures if the project target is not being achieved.

Assessment Models and Functional Indices

In the HGM Approach, an assessment model is a simple representation of a function performed by a wetland ecosystem. It defines the relationship between one or more characteristics or processes of the wetland ecosystem or surrounding landscape and the functional capacity of a wetland ecosystem. Functional capacity is simply the ability of a wetland to perform a function compared with the level of performance in reference standard wetlands.

Model variables represent the characteristics of the wetland ecosystem and surrounding landscape that influence the capacity of a wetland ecosystem to perform a function. Model variables are ecological quantities that consist of five components (Schneider 1994): (a) name, (b) symbol, (c) measure of the variable and procedural statement for quantifying or qualifying the measure directly, or calculating it from other measurements, (d) set of values (i.e, numbers, categories, or numerical estimates[1]) generated by applying the procedural statement, and (e) units on the appropriate measurement scale. Table 4 provides several examples.

Table 4
Components of a Model Variable

Name (Symbol)	Measure/Procedural Statement	Resulting Values	Units (Scale)
Sediment Delivery (V_{SED})	Potential for sediment delivery to the wetland/visually determine soil grain size, measure slopes and distances of surrounding uplands, determine land use	Continuous from 0 to >100	Unitless (nominal scale)
Duration of Inundation (V_{DURAT})	Average number of weeks per year that the wetland is inundated (flooded) with water/either measured directly or may be estimated based on vegetation indicators or Cowardin et al. (1979) classification	0 to 52	Weeks (interval scale)
Percent Coverage by Native versus Non-native Plants (V_{NPCOV})	Percentage of each plant community within each wetland zone that is occupied (coverage) by native plants.	0 to 100	% (% scale)

Model variables occur in a variety of states or conditions in reference wetlands. The state or condition of the variable is denoted by the value of the measure of the variable. For example, tree basal area, the measure of the tree canopy biomass variable, could be large or small. Similarly, recurrence interval, the measure of overbank flood frequency variable, could be frequent or infrequent. Based on its condition (i.e., value of the metric), a model variable is

[1] S. G. Leibowitz, and J. B. Hyman. (1997). "Use of scale invariance in assessing the quality of judgment indicators" (unpublished manuscript).

assigned a variable subindex. When the condition of a variable is within the range of conditions exhibited by reference standard wetlands, a variable subindex of 1.0 is assigned. As the condition deflects from the reference standard condition (i.e., the range of conditions that the variable occurs in reference standard wetland), the variable subindex is assigned based on the defined relationship between model variable condition and functional capacity. As the condition of a variable deviates from the conditions exhibited in reference standard wetlands, it receives a progressively lower subindex reflecting its decreasing contribution to functional capacity. In some cases, the variable subindex drops to zero. For example, when the potential for sediment delivery is extraordinarily high, as when the land use factor in the upland, low prairie, and wet meadow zones approaches 0.0, the variable subindex score for V_{SED} is 0. In other cases, the subindex for a variable never drops to zero. For example, regardless of the condition of a site or if the entire wetland is covered by nonnative plants, V_{NPCOV} will always be greater than zero.

Model variables are combined in an assessment model to produce a Functional Capacity Index (FCI) that ranges from 0.0 to 1.0. The FCI is a measure of the functional capacity of a wetland relative to reference standard wetlands in the reference domain. Wetlands with an FCI of 1.0 perform the function at a level that is characteristic of reference standard wetlands. Decrease in the FCI indicates the capacity of the wetland to perform the function is less than that which is characteristic of reference standard wetlands.

Application Protocols

The final component of the HGM Approach is the assessment protocol, which consists of specific instructions that allow the end user to assess the functions of a particular wetland area using the functional indices in the Regional Guidebook. The first task is characterization, which involves describing the wetland ecosystem and the surrounding landscape, describing the proposed project and its potential impacts, and identifying the wetland areas to be assessed. The second task is collecting the field data for model variables. The final task is analysis, which involves calculation of functional indices.

Development Phase

The Development Phase of the HGM Approach is ideally carried out by an interdisciplinary team of research scientists and regulatory managers to form an Assessment Team, or A-Team. The product of the Development Phase is a Regional Guidebook for assessing the functions of a specific regional wetland subclass. In developing a Regional Guidebook the A-Team completes the following major tasks: (a) apply the principles of HGM classification to define and characterize the regional wetland subclass, (b) conceptualize assessment models and their constituent variables, (c) identify and collect data from reference wetlands, (d) analyze the reference wetland data and describe the relationship

between metric variation and index of function, and (e) develop assessment protocols for applying the Regional Guidebook.

After the A-Team is organized and trained, its first task is classifying the wetlands within the region of interest into regional wetland subclasses using the principles and criteria of the HGM Classification (Brinson 1993; Smith et al. 1995). Next, focusing on a specific regional wetland subclass, the A-Team develops an ecological characterization or functional profile of the subclass. The A-Team then identifies the important wetland functions, identifies model variables to represent the characteristics and processes that influence each function, defines metrics for quantifying model variables, and constructs conceptual assessment models. Next, reference wetlands are identified to represent the range of variability exhibited by the regional subclass. Field data are then collected from the reference wetlands and used in the revision, calibration, and verification of the conceptual assessment models. Finally, the A-Team develops the assessment protocols necessary for regulators, managers, consultants, and other end users to apply functional indices in the assessment of wetland functions.

Application Phase

The Application Phase of the HGM Approach involves two steps. The first is using the data collection and assemblage protocols to assemble previously collected data from existing databases (e.g., maps, hydrologic data, soil survey data) and site-specific field data collected onsite. These data are then analyzed to develop site-specific assessments of the current wetland function. The second step is applying the results of the assessment (i.e., FCI) to the specific permit review sequence, which includes alternatives analysis, minimization, assessment of unavoidable impacts, determination of compensatory mitigation, design and monitoring of mitigation, comparison of wetland management alternatives or results, determination of restoration potential, or identification of acquisition or mitigation sites.

3 Characterization of Intermontane Prairie Pothole Wetlands

Regional Wetland Subclass and Reference Domain

This Regional Guidebook was developed to assess the ecological functions of intermontane prairie potholes. These wetlands are located in high concentration in many of the glaciated valleys of the northern Rocky Mountains that were sculpted by alpine glaciers during the last glacial period. Many of these intermontane valleys have climatic regimes that favor the development of a prairie-type vegetation dominated by short grasses. Two of the most prevalent areas regionally containing extensive pothole complexes can be found in the Flathead Valley south of Flathead Lake in the region locally known as Ninepipe and in the Blackfoot Valley north of Ovando, both in western Montana (Figure 1).

According to Smith et al. (1995) the reference domain is the geographic area that can be applied within the constraints of the reference wetland sites. The reference domain for this guidebook encompasses all of the intermontane glaciated valleys of western Montana. An examination was also conducted to determine the extent to which this Guidebook may be applied to areas along the east slope of the Rocky Mountains where alpine glaciers extended into the foothills and out into the Great Plains. Preliminary investigations suggest that there is sufficient similarity to justify this extension.

Description of the Regional Subclass

The Rocky Mountains of northwestern Montana are formed of sedimentary bedrock from the late Paleogene to the Proterozoic that has been affected by low-grade metamorphosis. These mountain ranges are part of the Rocky Mountain Belt Supergroup and consist of argillites, siltites, and carbonates with a maximum stratigraphic thickness of 5,200 m (Whipple et al. 1984). Colluvium and glacial till mantle the valleys. During the end of the last major glaciation of the

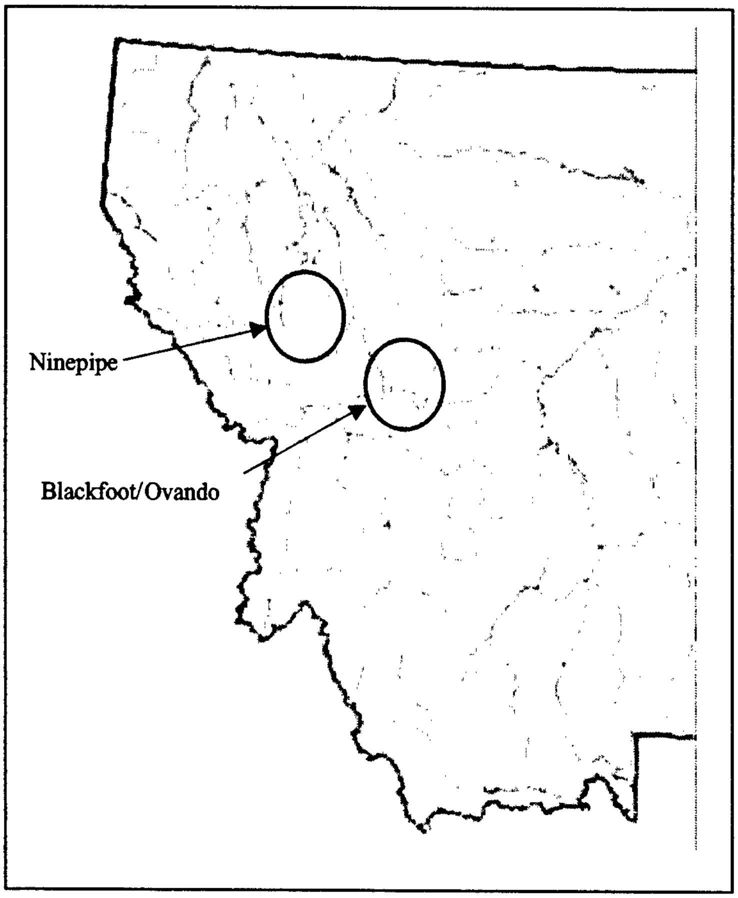

Figure 1. Watersheds map of western Montana highlighting areas of reference wetlands

Pleistocene, about 20,000 years ago, the valleys of western Montana were covered by glacial ice. The main glacial advance flowed from the cordilleran ice sheet down the Rocky Mountain Trench to the southern terminus, the Flathead Valley. Smaller valley glaciers flowed from the Livingston, Whitefish, Swan, Flathead, Mission, and Garnet Ranges to merge along the valley floors forming trunk glaciers as much as 1,000 m thick. Alluvial valley segments of tributary drainages formed with faulting and local accumulations of valley fill from alluvial and glacial sources. Ice dams in the Purcell Trench in northern Idaho resulted in the periodic filling of Lake Missoula and catastrophic flooding when the ice dam broke, sending water across eastern Washington.

Pothole wetlands of the region were formed basically in one of two ways: (a) as kettle depressions from ice blocks deposited at the terminus of a retreating glacier, as in the Ninepipe area of the Flathead Valley (Figure 2), and (b) as depressions and hummocks from a disintegration glacier, as in the Ovando area of the Blackfoot Valley (Figure 3). The resulting depressions on the landscape are often interconnected with hydrologic flow pathways that are relicts of the vast quantity of meltwater from the glaciers. The potholes are generally underlain by fine sediment deposited within the depression at the time of origin, and again associated with fine glacial sediment. These fine-grained sediments, often composed of glacial flour or very fine clay material, form a layer of low hydraulic

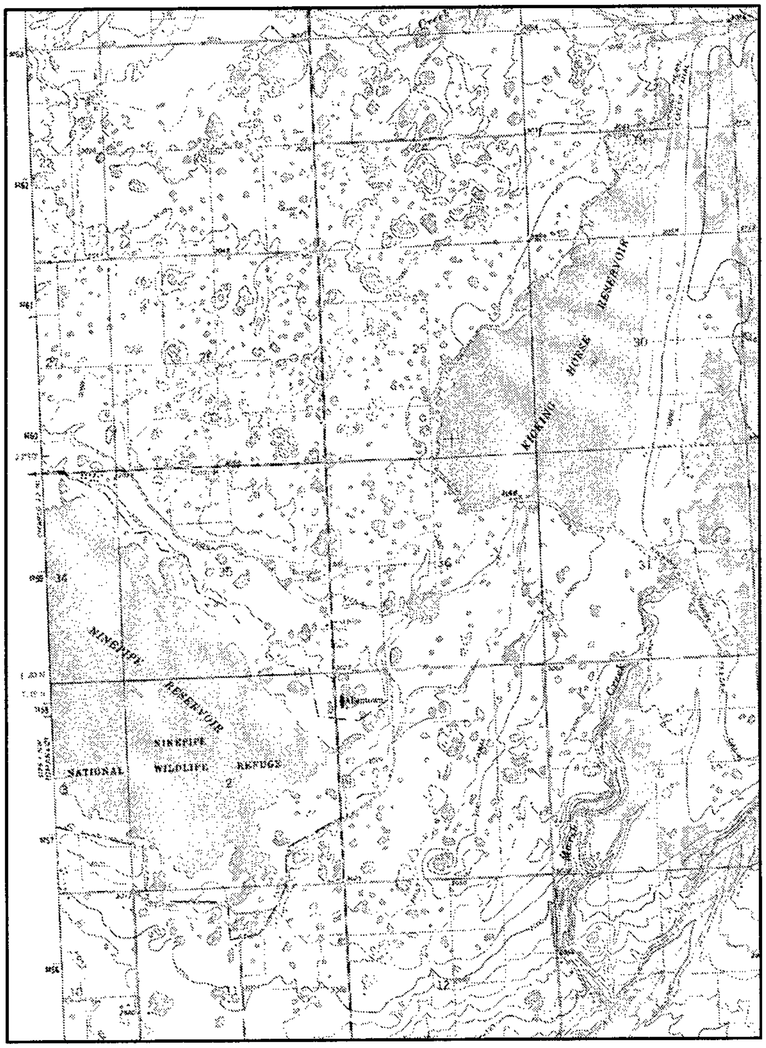

Figure 2. The Ninepipe area of the Ft. Connah U.S. Geological Survey (USGS) Quadrangle map

permeability that can result in a perching of water whenever a pothole is above the water table depth. The variation in glacial origin, geomorphology, and connectivity to groundwater sources establishes a significant portion of the natural variability in the functions of these depressional wetlands.

This Guidebook uses the terminology of Stewart and Kantrud (1971) to describe a mixture of four wetland zones within Intermontane Prairie Pothole Wetlands: Low Prairie, Wet Meadow, Shallow Marsh, and Deep Marsh. These four zones are characterized by distinctive vegetation responding to hydrogeomorphic ecosystem drivers. The wetlands described herein are surrounded by an Upland that, in its undisturbed state, is dominated by Palouse Prairie. The Upland vegetation is composed of a variety of grass and broadleaf species that are typical of relatively low precipitation grasslands of the Northern Rocky Mountains. The Upland vegetation is not dependent upon, not does it reflect, the proximity of wetlands.

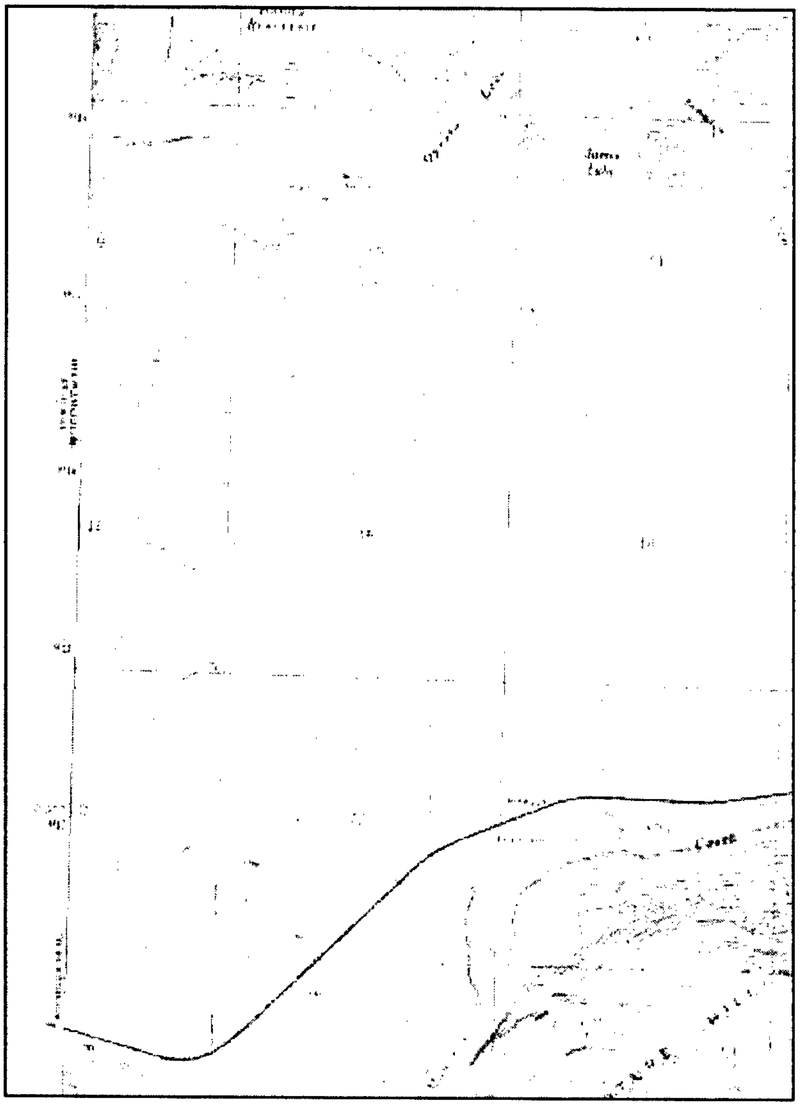

Figure 3. The Bandy Ranch Area on the Ovando USGS Quadrangle map in the Blackfoot Valley north of Ovando, MT

The Low Prairie wetland zone is composed primarily of upland species that demonstrate properties of being under the influence of soil moisture that is greater than that of the Upland. Thus, the Low Prairie zone is generally characterized by a species complex similar to the Upland, but individuals are often more robust than their counterparts in the Upland. The Low Prairie does not encompass jurisdictional wetland properties, but nearly always surrounds Intermontane Prairie Pothole Wetlands. The Low Prairie zone also has important characteristics that greatly influence many of the wetland functions described and assessed in this Guidebook. The Low Prairie acts as a buffer surrounding the depressional wetland and plays a significant role in protecting the wetland from the influence of land management on the Upland.

Intermontane Prairie Pothole Wetlands with a shallow geomorphology that generally does not intercept the groundwater are generally characterized by a hydrologic regime that expresses short-term flooding. Cowardin et al. (1979) refer to these as temporarily flooded wetlands. Stewart and Kantrud (1971) classify these wetlands as wet meadows. This Guidebook refers to that portion of the wetland that is temporarily flooded as the Wet Meadow Wetland Zone, or simply Wet Meadow. The Wet Meadow zone is characterized by hydric soils and hydrophytic vegetation (e.g., *Carex* spp., *Juncus balticus, Eleocharis palustris*) that does not require flooded conditions for extended periods. The Wet Meadow zone may cover the entire wetland surface area below the Low Prairie or may appear as a band expressing these characteristics surrounding a seasonally, semi-permanently, or permanently flooded wetland (Figure 4).

Pothole wetlands with deeper geomorphic basins that intercept the annual water table fluctuation zone or penetrate into the permanent water table will generally have, in addition to a Low Prairie and Wet Meadow, a Shallow Marsh and, if sufficiently deep, a Deep Marsh (Figures 4 and 5). The Shallow Marsh is characterized by emergent vegetation that is flooded throughout most, if not all, of the growing season (e.g., *Typha latifolia, Scirpus acutus*). The Deep Marsh is permanently flooded and is characterized by a depth between 1 and 2 m and submerged macrophytes (e.g., *Potomogeton* spp.).

The climate of the northern Rocky Mountains of western Montana is generally dominated by a Pacific maritime influence. Precipitation in the region generally comes from storms that enter the continental land mass from the central or northern Pacific Ocean. Recent understanding of global atmospheric circulation patterns and the effects of El Niño Southern Oscillation (ENSO) on regional weather and climate have revealed a cause and effect relationship between Pacific barometric patterns and annual variability in regional precipitation and temperature. Precipitation in the grassland prairies of the intermontane valleys varies between 0.3 and 0.5 m (12 and 20 in.) annually (Table 5).

Current understanding of the relationship between groundwater and prairie pothole wetlands has come primarily from research in the Great Plains reference domain. These research efforts, based on detailed instrumentation of piezometers and observation wells, have shown not only that water losses from pothole depressional wetlands occur through recharge to the groundwater, but also that transpiration may play a very significant role in water losses from the wetland (Winter and Rosenberry 1995). As discussed previously, the duration of inundation plays a major role in the character of many wetland functions (e.g., elemental cycling, vegetation). Although the effect of transpiration has been documented in discharge wetlands (Rosenberry and Winter 1997), transpiration is also important in groundwater flux and duration of flooding in recharge wetlands (van der Kamp and Hayashi 1998). Although it has been demonstrated that larger woody species with extensive root systems near the wetland can have a significant effect on transpiration rates and groundwater table depth, transpiration-induced hydrologic flow reversals are common also with grass- and herb-dominated uplands. Movement of water and salts as a result of transpiration particularly

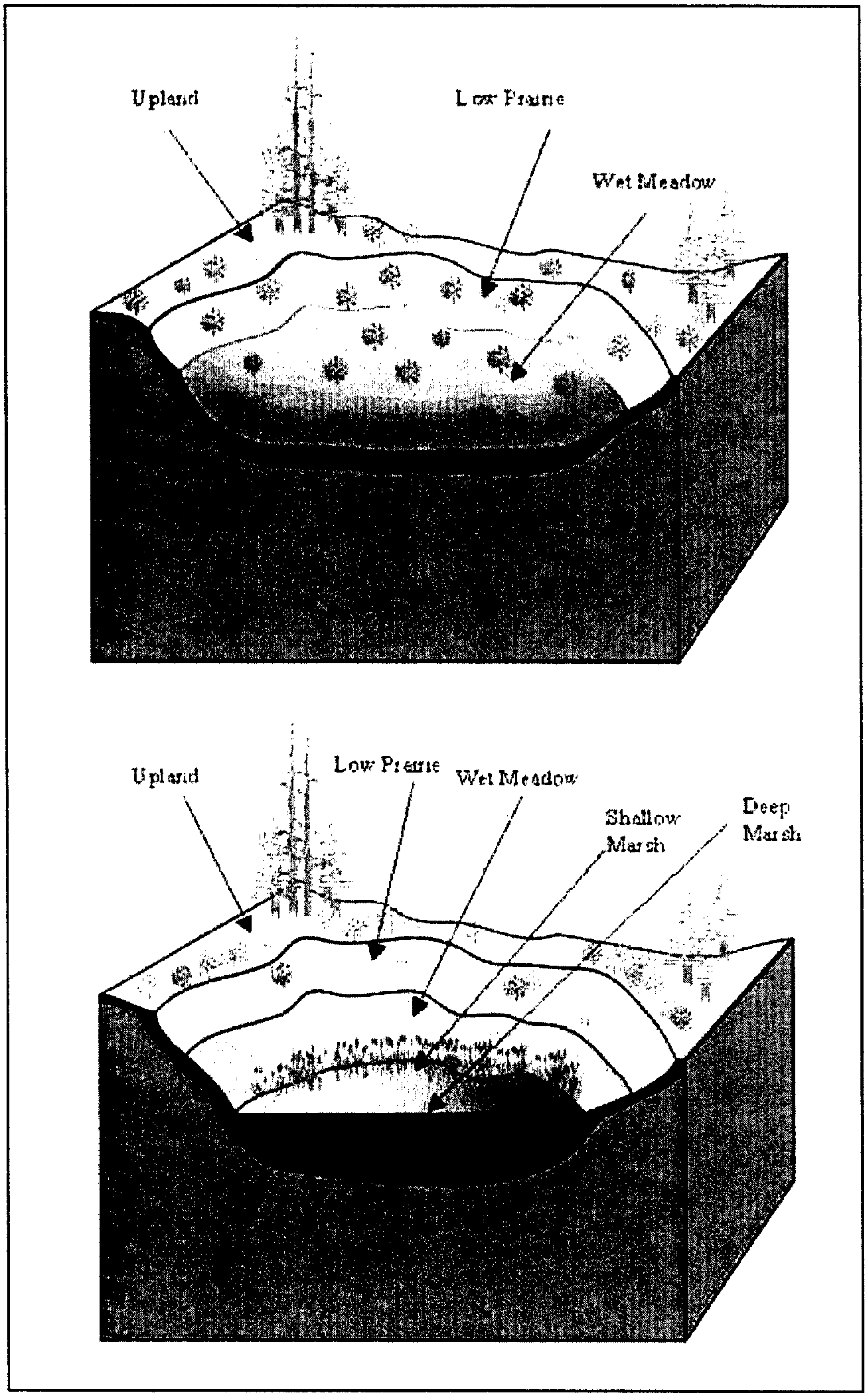

Figure 4. Two wetland types typical of the Intermontane Prairie Potholes. The upper panel shows a pothole wetland having only Low Prairie and Wet Meadow zones. The lower panel shows a pothole having Low Prairie, Wet Meadow, Shallow Marsh, and Deep Marsh zones

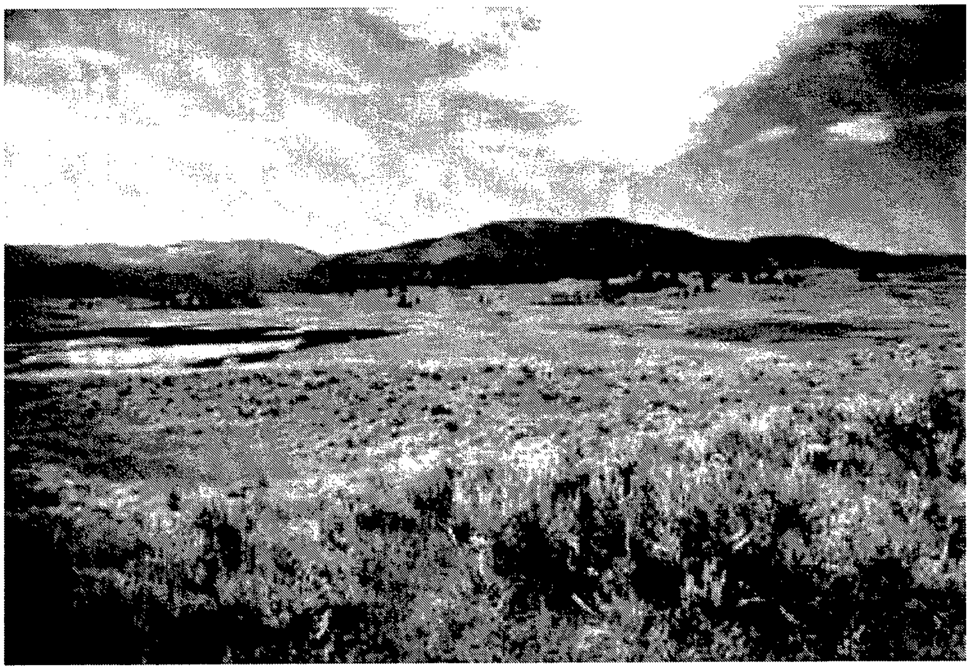

Figure 5. Two large pothole wetlands illustrating the complexity of vegetation communities. The large, permanently flooded wetland on the left side of the photo has a large Deep Marsh wetland zone and a heavily vegetated Shallow Marsh. The large wetland on the right is a semi-permanently flooded wetland dominated by a large area of Shallow Marsh

affects wetland margins and provides some of the explanation for hydric soil morphology and chemical characteristics (Arndt and Richardson 1992, 1993).

To use this Guidebook, it is essential that the user have a working knowledge of wetland zone characterization. Seasonal variation in rainfall, snow accumulation and melt, evapotranspiration, water table, and the geomorphology of each basin are reflected in the water level fluctuations within these wetlands. Plant communities in these Intermontane Prairie Potholes also reflect these hydrogeomorphic regimes. For review, please see the following: Cowardin et al. (1979); Kantrud, Krapu, and Swanson (1989); LaBaugh, Winter, and Rosenberry 1998); Richardson, Arndt, and Freeland 1994; Stewart and Kantrud (1971, 1972).

Table 5
Long-term Maximum and Minimum Monthly Temperatures, Mean Monthly Precipitation, and Mean Monthly Snowfall at Gauging Sites near St. Ignatius and Ovando, MT

Month	Average Temperature, °F		Average Precipitation, in.	Average Snowfall, in.
	Maximum	Minimum		
St. Ignatius, MT Period of Record 2/6/1896 to 7/31/1998				
January	32.9	16.7	0.96	11.8
February	38.5	20.4	0.78	8.4
March	47.6	25.8	1.05	6.6
April	58.9	32.8	1.4	1.8
May	67.4	39.5	2.28	0.3
June	74.9	45.5	2.46	0
July	84.4	49.5	1.15	0
August	83	48.1	1.16	0
September	71.3	41	1.43	0.1
October	58.3	33.5	1.18	1.1
November	42.9	26.1	1.06	6
December	35.1	20.2	0.99	9.6
Annual Mean	58	33.3	15.91	45.7
Ovando, MT Period of Record 6/1/1899 to 5/31/1976				
January	27.1	5.3	1.73	20.5
February	32.9	8.6	1.25	14.6
March	40.9	16	1.14	9.5
April	54	25.9	0.89	3.3
May	63.9	32.6	1.84	0.6
June	71.2	38.6	2.25	0
July	81.9	41.6	1.01	0
August	80.6	39.2	1.01	0
September	69.7	32.3	1.29	0.5
October	57.5	25.7	1.22	2.8
November	40.4	17.8	1.5	10.5
December	30.1	10.3	1.75	17.8
Annual Mean	54.3	24.5	16.87	80.1

Note: To convert °F to Celsius, use the following formula: C = (5/9)(F-32). To convert to Kelvin readings, use: K = (5/9)(F-32) + 273.15. To convert inches to meters, multiply by 0.0254.

4 Wetland Functions and Assessment Models

Overview

The following functions are performed by Intermontane Prairie Pothole Wetlands in the Northern Rocky Mountains:

a. Surface Water Storage.

b. Nutrient Cycling.

c. Retention of Elements, Compounds, and Particulates.

d. Maintain Characteristic Plant Community.

e. Maintain Characteristic Invertebrate Food Webs.

f. Maintain Characteristic Vertebrate Habitats.

g. Maintain Wetland Interspersion and Connectivity.

Each of these functions will be presented and the variables and models on which the assessment is based will be discussed in the following sequence:

a. *Definition*: Defines the function and identifies an independent quantitative measure that can be used to validate the functional index.

b. *Rationale for Selecting the Function:* Provides the rationale for selecting a function and discusses onsite and offsite effects that may occur as a result of lost functional capacity.

c. *Characteristics and Processes that Influence the Function:* Describes the characteristics and processes of the wetland and the surrounding landscape that influence the function and lays the groundwork for the description of model variables.

d. Description of Model Variables: Defines and describes each of the variables in the assessment model.

e. FCI: Describes the assessment model from which the FCI is derived, and discusses how model variables interact to influence functional capacity.

Function 1: Surface Water Storage

Definition

The function Surface Water Storage is defined as the capacity of the depressional wetland to store water (Figure 6). The annual water budget of depressional wetlands is under the influence of precipitation or snowmelt within the catchment and through the interception of the groundwater table. Thus, surface water storage is that portion of the water budget that is generally above the groundwater saturation zone plus that maintained by the water table. Snowmelt and storm runoff are collected and stored temporarily in wetland basins. Temporary storage is lost to evapotranspiration or to groundwater. Storage alters the amount and timing of runoff from a catchment into streams and recharge to groundwaters. Surface water adds soil moisture to the unsaturated zone and interacts with long-term groundwaters and water elevations within depressional wetlands largely under the control of groundwater.

Typically, long-term surface water storage is that portion of the water budget that is carried over from year to year. Long-term surface waters are highly interactive with local groundwater flows. This function is affected by both evapotranspiration and groundwater properties of the local area. Surface water has a significant effect on biogeochemical cycling and in particular has a very strong effect on vegetation and invertebrate and vertebrate populations. Potential independent, quantitative measures for validating the functional index include data of catchment precipitation, depression storage, evapotranspiration, water table elevations, and vertical hydraulic gradient.

Rationale for selecting the function

Performance of the function Surface Water Storage permits the wetland to retain surface water inputs for a sufficient period of time to develop other wetland characteristics (e.g., hydric soils, hydrophytic vegetation). All depressional wetlands perform this function to various degrees. Temporarily to seasonally flooded wetlands (sensu Stewart and Kantrud 1972) perform this function without geomorphic interception of the water table, while semipermanent to permanently flooded wetlands generally intercept the water table. Many glacial pothole wetlands of the Northern Rocky Mountains are perched well above the natural fluctuation of the local groundwater table. As in the prairie pothole region of the Northern Great Plains, the principal source of water that results in the temporary or seasonal flooding of depressional wetlands is precipitation and runoff from

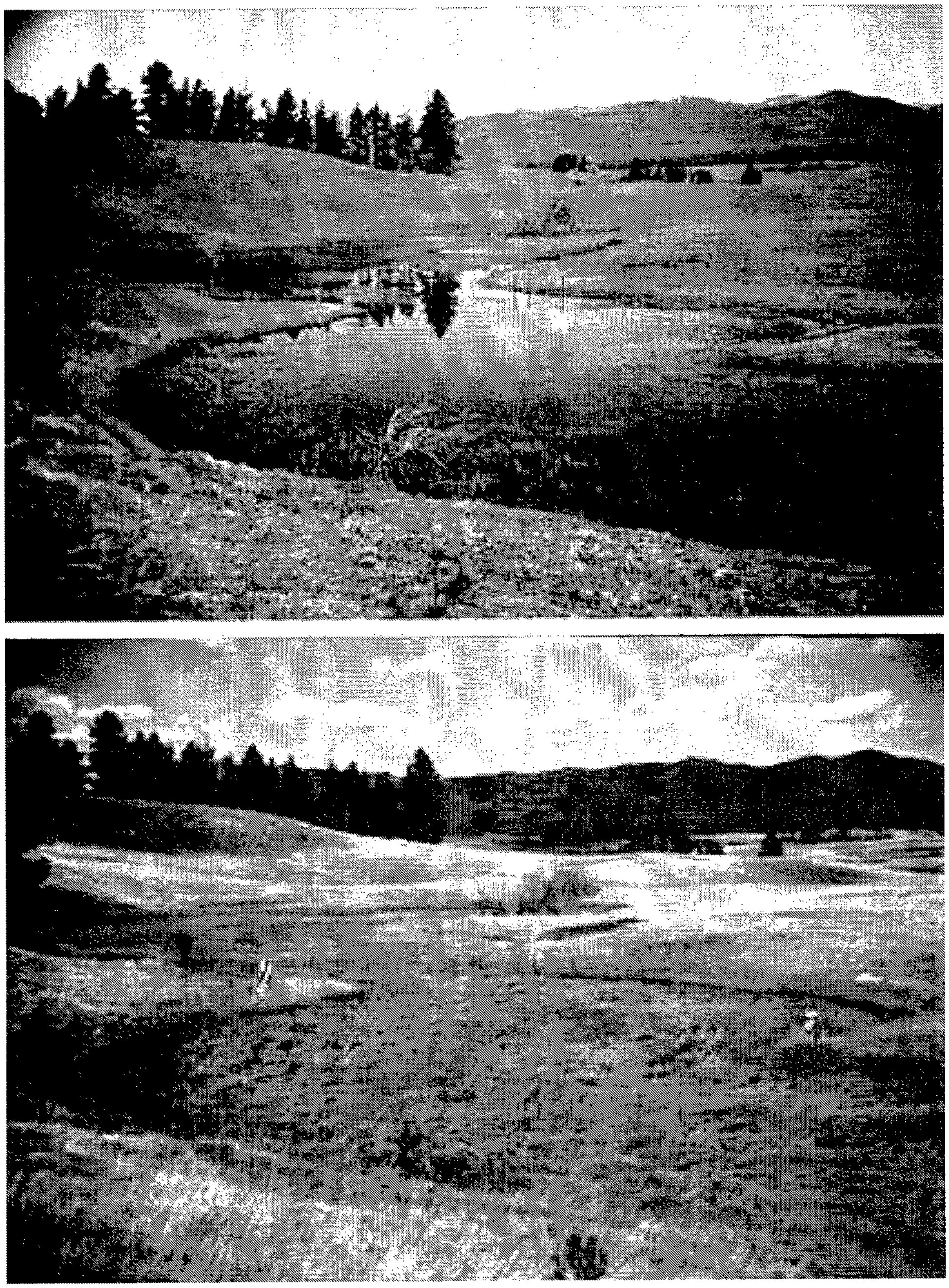

Figure 6. A pothole wetland dominated by a Shallow Marsh wetland zone. The top photo was taken in the spring prior to the growth of emergent vegetation. The bottom photo was taken in the late summer. These illustrate the importance of seasonal variability in water storage

snowmelt. Loss of water that has been dynamically stored occurs through evapotranspiration or recharge to groundwater. Groundwater recharge is controlled by the hydrologic conductivity of the soil parent material. The intermontane glacial potholes of the Northern Rocky Mountains generally occur in unconsolidated glacial till. The depressional wetlands distributed across the

surface of the till may or may not have fine clay lens materials deposited at the time of origin by either glacial outwash or glacial flour associated with interspersed ice blocks forming the depressions. Thus, depressional wetland soils and hydrologic conductivity are highly variable, leading to rapid draining or in contrast, prolonged water storage.

Surface Water Storage also has a significant effect on elemental cycling in the wetland. Prolonged saturation leads to anaerobic soil conditions and initiates chemical reactions that are highly dependent upon the redox capacity of the soil (Mausbauch and Richardson 1994). The oxygen concentration in wetland soils greatly affects the redox potential and the chemical cycling properties of elements and compounds, particularly nutrients. This function also has a very significant impact on invertebrate and vertebrate populations. Some invertebrates (e.g., midges) have very rapid life cycles and are highly adapted to ephemeral wetlands. On the other hand, many species (e.g., dragonflies) have much longer life histories and require ponded water conditions virtually throughout the year (Merritt and Cummins 1996). Likewise, many of the vertebrates that are obligatorily associated with aquatic environments (e.g., turtle, muskrat) require long periods of static water storage (Mitsch and Gosselink 1993).

Characteristics and processes that influence the function

The characteristics and processes that influence the capacity of a depressional wetland to store water are from both natural and anthropogenic origins. Climate, landscape-scale geomorphic characteristics, and characteristics of the soil within and around the wetland are factors largely established by natural processes. Anthropogenic alterations of a wetland (e.g., tilling, cattle grazing) also influence the way a wetland stores surface waters. Such effects may take the form of the dominant land use in and near the wetland and whether the wetland has been hydrologically modified through ditching or the placement of tile under the wetland to drain it.

The geomorphic origin of intermontane glacial potholes has a significant influence on the character of the wetland and its ability to store water (Chapter 3). The intermontane prairie potholes of the Northern Rocky Mountains were formed largely by either ice block integration into unconsolidated till in terminal moraine deposits during glacial recession or by glacial lobe abandonment, in which the leading segment of a valley glacier was separated from the advancing lobe and melted in place. The first process resulted in a relatively flat topographic surface with "kettle lake" type depressions (e.g., Ninepipe, Mission Valley). The second process resulted in a hummock and depression landscape with the hummocks formed by the till material that was carried by the glacier in crevasses and the depressions formed where the ice of the glacier came to rest (e.g., Bandy Ranch, Blackfoot Valley). The differences between these glacio-geomorphic processes greatly affect parent soil characteristics, groundwater flow pathways and even feasibility of different land uses.

Climatic conditions in the Northern Rocky Mountain intermontane valleys are generally characterized by cold, wet winters and warm, dry summers. Winter

snow, spring snowmelt, and spring rains are the dominant water sources that are stored for this function. Rarely does it rain sufficiently in summer to fully augment evapotranspiration losses during the dry months of July and August. Thus, depressional wetlands that do not intercept groundwaters or penetrate the water table are generally intermittently, temporarily, or seasonally flooded. The majority of the water budget of these wetland types is controlled by precipitation sources. Depressional wetlands that do intercept the mean groundwater table are generally semipermanently or permanently flooded and possess a Shallow Marsh and, if sufficiently deep, a Deep Marsh (sensu Stewart and Kantrud 1972).

The soil properties of intermontane glacial potholes are highly variable. Theoretically, at two ends of a continuum, coarse-textured glacial till permits high hydrologic conductivity and the rapid loss of dynamic waters to groundwater. In contrast, depressions may be lined with clay sediments from glacial flour or lacustrine origin that restrict hydrologic conductivity and result in stored waters above the groundwater table. Hence, for the former, storage is controlled by outputs through groundwater seepage and evapotranspiration, while storage is controlled for the latter virtually exclusively by evapotranspiration.

In addition to geomorphic and climatic processes, human activities may also have a profound effect on the storage of water within a glacial pothole. Modifications to the upland, wetland edge, or directly to the wetland may greatly affect the receipt and retention of water. Land use changes, such as soil compaction, cultivation, roads, and changes in evapotranspiration that result from grazing, are modifications that directly affect this function. Many depressional wetlands and/or the lands surrounding them are either grazed or cultivated, depending on dominant landform and characteristics that favor one land use type over another.

Ditching and/or tiling for the purpose of draining the wetland and putting it into crop production have modified many depressional wetlands. Such modifications so significantly affect the ability of the wetland to retain surface water that many such wetlands lose their wetland characteristics.

Description of model variables

Upland Land Use (V_{UPUSE}). This variable is a function of the various land uses in the upland above the outer edge of the wetland, generally characterized by the Low Prairie wetland zone. If the catchment boundary is extremely large or indistinct, then a perimeter of 100 m from the wetland edge is used as the functional upland zone of influence. Various land uses have different effects on the catchment and the ability of the wetland to dynamically store surface water. The calculation of this variable is based on the general land use of the upland over an extended period of time (i.e., past 10–20 years). This is referred to as the Catchment Land Use and is distinguished by the land use descriptions and scores in Table 6.

Table 6
Current Land Use Treatment in the Upland and Corresponding Variable Subindex Score

Current Land Use Treatment	Score
Commercial right-of-way or paved driveway	0.00
Private right-of-way or unpaved driveway	0.10
Heavy grazing by livestock	0.20
Annual crop production	0.20
Generalized soil disturbance	0.30
Residential or commercial lawn	0.40
Moderate grazing by livestock	0.50
Mowed and hayed, but uncultivated field	0.60
Light grazing by livestock	0.70
Conservation easement with planting	0.85
Fallow, no cultivation or livestock >2 years, but <10 years	0.90
Managed as undisturbed grassland >10 years, but <20 years	0.95
Managed as undisturbed grassland >20 years	1.00

Land Use in the Wetland Edge ($V_{EDGEUSE}$). This variable is a function of the various land uses within the Low Prairie wetland zone. If the Low Prairie is indistinct, then $V_{EDGEUSE}$ is based on the area above the Wet Meadow boundary to a distance of 25 m. The wetland edge serves as a buffer to the wetland. Various land uses have different effects within the Low Prairie and the ability of the wetland to dynamically store surface water. The calculation of this variable is based on the general land use within the Low Prairie surrounding the wetland over an extended period of time (i.e., past 10–20 years). This is referred to as the Wetland Edge (Low Prairie) Land Use and is distinguished by the land use descriptions and scores in Table 7.

Land Use in the Wetland (V_{WETUSE}). This variable is a descriptive metric of the level of disturbance within the wetland. This variable is extended to the Wet Meadow, Shallow Marsh, and Deep Marsh wetland zones (Stewart and Kantrud 1971). Various land uses have different effects within the wetland and on the ability of the wetland to dynamically store surface water. The calculation of this variable, therefore, is based on the general land use within the wetland over an extended period of time (i.e., past 10–20 years). Land use within these three wetland zones is referred to as V_{WETUSE} and is distinguished by the land use descriptions and scores in Table 8.

Table 7
Current Land Use Treatment in the Low Prairie Wetland Zone and Corresponding Variable Subindex Score

Land Use Treatment	Score
Current Use	
Heavy grazing by livestock	0.10
Annual crop production	0.10
Moderate grazing by livestock	0.40
Mowed and hayed, but uncultivated field	0.50
Light grazing by livestock	0.65
Conservation easement with planting	0.75
Fallow, no cultivation or livestock >2 years, but <10 years	0.90
Managed as undisturbed grassland >10 years, but <20 years	0.95
Managed as undisturbed grassland >20 years	1.00
Projected Use	
Fill with paving	0.00
Fill without paving	0.05
Partial fill	0.10

Table 8
Current Land Use Treatment in the Wet Meadow, Shallow Marsh, and Deep Marsh Wetland Zones and Corresponding Variable Subindex Score

Land Use Treatment	Score
Current Use	
Heavy grazing by livestock	0.10
Dry year crop production	0.20
Moderate grazing by livestock	0.30
Mowed and hayed, but uncultivated field	0.40
Light grazing by livestock	0.60
Fallow, no cultivation or livestock >2 years, but <10 years	0.80
Managed as undisturbed grassland >10 years, but <20 years	0.95
Managed as undisturbed grassland >20 years	1.00
Projected Use	
Fill with paving	0.00
Fill without paving	0.05
Partial fill	0.10

Soil Pore Space (V_{PORE}). This variable strongly affects the ability of a wetland to dynamically store surface water. Very fine-textured soils containing a significant fraction of clay particles have a much slower rate of hydrologic conductivity than do coarse-textured soils, which permit water to pass through them relatively quickly. When the parent material soils that underlie a wetland result in the retention of water through the prevention of water loss to the groundwater, the wetland will retain the water longer. Table 9 lists the subindex scores for soil types.

Table 9
Soil Texture Table and Corresponding Texture Index Score

Soil Texture	Variable Subindex Score
Gravel	0.00
Sand	0.33
Loamy sand	0.42
Sandy loam	0.50
Sandy clay loam	0.58
Loam	0.67
Silt loam	0.75
Silt	0.83
Sandy clay	0.92
Clay loam	1.00
Silty clay loam	1.00
Silty clay	1.00
Clay	1.00

Hydrologic Modification ($V_{HYDROMOD}$). This variable represents the change in duration of flooding within the wetland expressed as the number of weeks in the year that ponded water is present. This variable is based on the duration of flooding (i.e., water regime) in a typical water year since water storage can be significantly less following long-term drought or greatly extended following a long wet period. If possible, this variable should be evaluated directly by observation at the wetland site. If this is not possible, then indicators may be used to estimate the number of weeks of inundation during the year by observing soil and vegetation in the deepest part of the wetland basin. The least preferred estimate of duration would be based on National Wetlands Inventory (NWI) maps. Water regime within the wetland is based on the number of weeks of flooding and given a Cowardin et al. (1979) classification water regime score (Table 10).

Table 10
Duration of Wetland Flooding with Cowardin et al. (1979) Water Regime

Flooding Condition	Weeks Flooded	Water Regime
Temporarily flooded	1 - 4	A
Seasonally flooded	5 - 17	C
Semipermanently flooded	18 - 40	F
Intermittently exposed	41 - 51	G
Permanently flooded	52	H

Examples of direct hydrologic modification of the wetland include removal of water from the wetland for irrigation or supplementing the water budget by diverting runoff to the wetland. The latter is a common practice around transportation corridors. An example of indirect hydrologic modification is tilling or ditching the wetland to drain it for agriculture. The variable $V_{HYDROMOD}$ is scored by determining the number of weeks of the year the wetland floods under normative water budget conditions and projecting the change in duration in view of past or future projects. If the water regime is normative, then the current subindex score is 1.0. If there is a change in water regime, then the subindex score is determined by the matrix in Table 11, where the normative water regime is sited across the top row of the matrix table and the projected water regime is estimated and sited along the left of the matrix table. The intersection of normative and projected water regimes provides the subindex score.

Geomorphic Modification (V_{GEOMOD}). This variable represents the anthropogenic modification of the geomorphic properties of the wetland through changes either to increase water storage or drain the wetland. Examples of geomorphic modification commonly practiced are tilling or ditching wetlands to remove water or dredging and excavating wetlands to increase water depth. Wetlands have been drained in the past most often so that the wetland can be cultivated and put into crop production. However, ditching or tilling may also have been done near home sites to drain the area for lawns or simply to reduce the standing water on the property.

The modification to the wetland is geomorphic in nature but directly affects hydrologic properties. Filling, dredging, tilling, and ditching are all modifications that change the fundamental character of the wetland. This variable is calculated as a function of change on a per-area basis and is linked to wetland zonation and vegetation communities (Table 12).

Table 11
Matrix of Cowardin Water Regime in Which Subindex Scores Are Established by Determining the Normative and Projected Water Regimes

Altered Cowardin Water Regime \ Normative Cowardin Water Regime	A	C	F	G	H
A	1.0	0.7	0.5	0.2	0.1
C	0.7	1.0	0.7	0.5	0.2
F	0.5	0.7	1.0	0.7	0.5
G	0.2	0.5	0.7	1.0	0.7
H	0.1	0.2	0.5	0.7	1.0

Functional Capacity Index

The assessment model for calculating the FCI is as follows:

$$FCI = \left[\left(\frac{V_{UPUSE} + V_{EDGEUSE} + V_{WETUSE} + V_{PORE}}{4}\right) \times \left(\frac{V_{HYDROMOD} + V_{GEOMOD}}{2}\right)\right]^{1/2} \quad (1)$$

In the model equation the capacity of the wetland to temporarily store water depends on the following factors: (a) land use in the upland, along the wetland edge, and within the wetland, (b) the physical and hydrologic properties of the material under the wetland that control the rate of water loss to the groundwater, and (c) the effect of anthropogenic modification to the hydrology of the wetland through either increase or decrease in the water budget. Increase in the water budget may be the result of damming surface connections that permit water to flow out of the wetland or augmentation of inputs, such as in the directing of

Table 12
Calculation Matrix of Subindex Scores Based on Unaltered and Altered Geomorphic Conditions by Wetland Zone

Altered Wetland Zones	Unaltered Wetland Zones: Low Prairie	Wet Meadow	Shallow Marsh	Deep Marsh
Low Prairie	1.0	0.1	0.0	0.0
Wet Meadow	0.8	1.0	0.8	0.5
Shallow Marsh	0.2	0.8	1.0	0.8
Deep Marsh	0.0	0.2	0.8	1.0

surface runoff to the wetland (e.g., highway runoff). Decrease in the water budget may be the result of irrigation using the wetland as a water source or may be the direct result of ditching or tilling with the expressed intent of draining the wetland.

In the first part of the equation the land use surrounding (V_{UPUSE}) and within ($V_{EDGEUSE}$, V_{WETUSE}) the wetland are considered in conjunction with the hydrologic properties of the parent material (V_{PORE}) under the wetland. These variables indicated the land use effects on the wetland and the capacity of the wetland to retain dynamic, short-term water storage. The equation expresses these four variables as arithmetic means. Therefore all four variables would have to equal zero before this portion of the equation equals zero. Such a condition would be highly unusual, but could be possible where a wetland is surrounded by impervious surfaces, such as a parking lot, and the porosity of the soil is such that the texture is coarse gravel or cobble and as such has no capacity to hold standing water.

In the second part of the equation, $V_{HYDROMOD}$ and V_{GEOMOD} reflect various anthropogenic modifications in either the hydrologic regime or wetland geomorphology that result in change in water regime for the wetland as a whole

and change in wetland zonation, respectively. These modifications may be the result of ditching or tilling or supplementation of the water regime from redirected runoff. These variables are added and then multiplied by the previous four as a geometric mean for the equation.

Function 2: Nutrient Cycling

Definition

The function Nutrient Cycling is defined as the ability of the pothole wetland to transform abiotic essential elements and materials (e.g., carbon dioxide, water, phosphorus, nitrogen) needed for biological processes into organic forms (e.g., carbohydrates, fats, proteins) and to oxidize those organic molecules back into elemental forms through decomposition. Thus, nutrient cycling includes the biogeochemical processes of producers, consumers, and decomposers. Potential independent, quantitative measures for validating the functional index include standing stock of living and/or dead biomass, gm/m^2; net annual primary productivity gm/m^2, annual accumulation of organic matter, gm/m^2; and annual decomposition of organic matter, gm/m^2.

Rationale for selecting the function

Nutrient cycling is a fundamental function performed by all ecosystems, but tends to be accomplished at particularly high rates in many wetland systems (Mitsch and Gosselink 1993). A sustained supply of nutrients in the soil provides for maintenance of the characteristic plant community including annual primary productivity, composition, and diversity. The plant community (producers) provides the food and habitat structure (energy and materials) needed to maintain the characteristic animal community (consumers). In time the plant and animal communities serve as a source of detritus that is the source of energy and materials needed to maintain the characteristic community of decomposers. The decomposers break down these organic materials into simpler elements and compounds that can reenter the nutrient cycle.

The ability of a pothole wetland to perform this function is dependent upon the transfer of elements and materials between trophic levels within the wetland, the rates of decomposition, and the flux of materials in and out of the wetland. A change in the ability of one trophic level to transform materials will result in changes in the transformation of materials in other trophic levels (Carpenter 1988). Wetlands, as the ecotone between terrestrial and aquatic environments (Naiman, Decamps, and Fournier, ed. 1989), are particularly subject to anthropogenic change within a watershed that affects material transport from outside the wetland proper. These changes may greatly affect the way the pothole wetland performs this function.

Characteristics and processes that influence the function

Nutrient cycling or biogeochemical cycling is probably best known through plants and the processes of photosynthesis and respiration. Oxygen is needed for respiration, and the diffusion of oxygen in water is 10,000 times slower in water than in air. Wetland plants, hydrophytes, are unique in that they have adapted to living in water or wet soil environments. Physiological adaptations in leaves, stems, and roots allow for greater gas exchange, permit respiration to take place, and allow the plant to harvest the stored chemical energy it has produced through photosynthesis. Although there is no clear starting or ending point for nutrient cycling, it can be argued that it is the presence of water in the wetland that determines the characteristic plant community of hydrophytes. In turn, it is the maintenance of the characteristic primary productivity of the plant community that sets the stage for all subsequent transformation of energy and materials at each trophic level within the wetland. It follows that alterations to hydrologic inputs, outputs, or storage and/or changes to the characteristic plant community will directly affect the way in which the wetland can perform this function.

The ideal approach for assessing nutrient cycling in a pothole wetland would be to measure the rate at which elements and materials are transferred and transformed between and within each trophic level over several years. However, the time and effort required to make these measurements are well beyond a rapid assessment procedure. However, reference data suggest that land use practices and current treatments within the wetland have great effect on the characteristic plant community structure (species composition and coverage), diversity, and primary productivity. Soil profile characteristics, particularly the depth and color of the O and A horizons, are indicators of long-term nutrient supply and a characteristic decomposer community. It is assumed that measurements of these characteristics reflect the level of nutrient cycling taking place within a wetland. Comparison of these data, between a target wetland and the characteristics of reference standard wetlands, indicates changes in the level of nutrient cycling.

Description of model variables

Land Use in the Wetland (V_{WETUSE}). This variable is a function of the various land uses within the wetland. For this Guidebook, this area is categorized as the Wet Meadow, Shallow Marsh, and Deep Marsh wetland zones (Stewart and Kantrud 1972). There is considerable hydrogeomorphic variability among wetlands within this HGM class. Intermittent and temporary wetlands may possess only a Wet Meadow wetland zone to the center of the wetland, whereas semipermanent and permanent wetlands may possess a Wet Meadow, Shallow Marsh, and Deep Marsh. Land use within the wetland directly affects nutrient cycling in the wetland by contributing to the movement of material that may be bound in the sediments up into surface waters. For example, if a temporary or seasonally flooded wetland is tilled in drought years, the turning of the soil will directly affect the rate at which elements that are typically bound in the wetland sediments are released to surface waters. Another example of effects of land use is cattle grazing, which increases removal of vegetation from the wetland, but also increases nutrient loading to the wetland from animal waste and soil disturbance.

The calculation of this variable is based on the general land use within the Wet Meadow, Shallow Marsh, and Deep Marsh over an extended period of time (i.e., past 10–20 years). Land use within these three wetland zones is referred to as V_{WETUSE} and is distinguished by the land use descriptions and scores presented in Table 13.

Table 13
Current Land Use Treatment in the Wet Meadow, Shallow Marsh, and Deep Marsh Wetland Zones and Corresponding Variable Subindex Score

Land Use Treatment	Score
Current Use	
Heavy grazing by livestock	0.10
Dry year crop production	0.20
Moderate grazing by livestock	0.30
Mowed and hayed, but uncultivated field	0.40
Light grazing by livestock	0.60
Fallow, no cultivation or livestock >2 years, but <10 years	0.80
Managed as undisturbed grassland >10 years, but <20 years	0.95
Managed as undisturbed grassland >20 years	1.00
Projected Use	
Fill with paving	0.00
Fill without paving	0.05
Partial fill	0.10

Land Use in the Wetland Edge ($V_{EDGEUSE}$). This variable is a function of the various land uses along the edge of the wetland. This is generally categorized as the Low Prairie wetland zone (Stewart and Kantrud 1972). If the Low Prairie is indistinct, then $V_{EDGEUSE}$ is based on the area above the Wet Meadow wetland zone to a distance of 25 m.

Land use along the wetland edge has a significant effect on nutrient cycling within the wetland. The wetland edge is particularly vulnerable to tilling in drought years. The turning of the soil will directly affect the rate at which elements that are typically bound in the wetland edge sediments are released to surface waters.

The calculation of this variable is based on the general land use within the Low Prairie surrounding the wetland. This is referred to as the Wetland Edge Land Use ($V_{EDGEUSE}$) and is distinguished by the land use descriptions and the Variable Subindex Scores found in Table 14.

Table 14
Current Land Use Treatment in the Low Prairie Wetland Zone and Corresponding Variable Subindex Score

Land Use Treatment	Score
Current Use	
Heavy grazing by livestock	0.20
Annual crop production	0.20
Generalized soil disturbance	0.30
Residential or commercial lawn	0.40
Moderate grazing by livestock	0.50
Mowed and hayed, but uncultivated field	0.60
Light grazing by livestock	0.70
Conservation easement with planting	0.85
Fallow, no cultivation or livestock >2 years, but <10 years	0.90
Managed as undisturbed grassland >10 years, but <20 years	0.95
Managed as undisturbed grassland >20 years	1.00
Projected Use	
Fill with paving	0.00
Fill without paving	0.05
Partial fill	0.10

Decomposition of Organic Matter ($V_{ORGDECOMP}$). This variable represents the long-term store of organic matter and nutrients. It is also an indicator of the characteristic decomposer community of the wetland. The soil O horizon is composed largely of organic materials derived from dead plant tissue and, to a lesser extent, animals. What were originally plants and animals are residues at various stages of decomposition; hence, they are both a nutrient store and source for the wetland. Departures in the depth of the O horizon from reference standards are indicators of too little or too much organic nutrient additions to the wetland or too fast or too slow a rate of decomposition, based on reference standard. Too few or too many nutrient additions or significant departures from reference standards of decomposition rates will interfere with the sustainability of the wetland to perform this function.

The soil A horizon is a surface mineral soil characterized by the accumulation of humus. Humus is black, highly decomposed, and naturally colloidal (i.e., has a small particle size, large surface area, and net negative charge). Its ability to hold nutrients is greater than that of any other soil constituent. The depth and color of the A horizon are indexes of the ability of the soil to store nutrients for plant availability. Departures from reference standards are indicators of changes in long-term organic matter inputs. A thin, light-colored A horizon may be the result of lowered productivity caused by management. An A horizon having a thickness greater than reference standard is likely the result of accelerated erosion from adjacent uplands. $V_{ORGDECOMP}$ is calculated as an Organic Matter Decomposition

Factor based on the Munsell Soil Color Chart chroma and hue of the A horizon in the Wet Meadow wetland zone and the added depths (cm) of the A and O horizons, also in the Wet Meadow. The Organic Matter Decomposition Factor is calculated as

$$OMDF = \left(\frac{(ChromaA \times HueA \times DepthA)}{10} + DepthO \right) \tag{2}$$

The Variable Subindex Score for $V_{ORGDECOMP}$ is based on the relationship between the Organic Matter Decomposition Factor and the Variable Subindex Score illustrated in Figure 7.

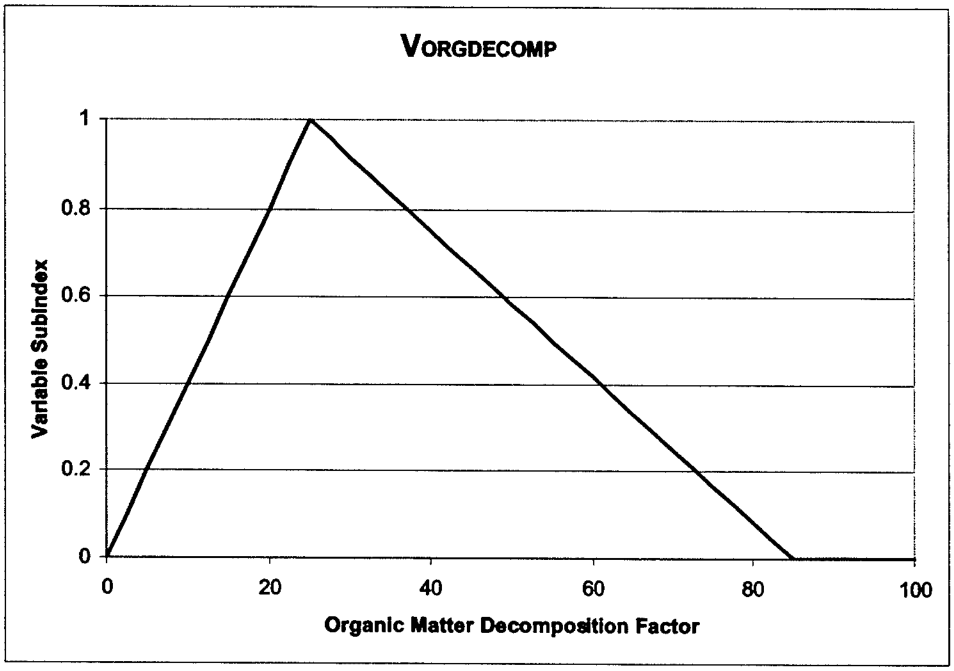

Figure 7. Correlation between Organic Matter Decomposition Factor (OMDF) and the Variable Subindex Score

Soil Pore Space (V_{PORE}). This variable directly affects the nutrient cycling of the wetland. Not only do very fine textured soils containing a significant fraction of clay particles have a much slower rate of hydrologic conductivity than coarse-textured soils, which permit water to pass through them relatively quickly, but sediments of different character have distinctly different abilities to retain or release nutrients (Ellis and Stanford 1988).

The metric for this variable is based on the texture, and thus hydrologic conductivity, of the C horizon of the Wet Meadow soil. The standardized soil texture triangle given in Figure 8 is used to determine soil texture. Then, using Table 15, the corresponding Variable Subindex Score is obtained for the soil texture in the wetland.

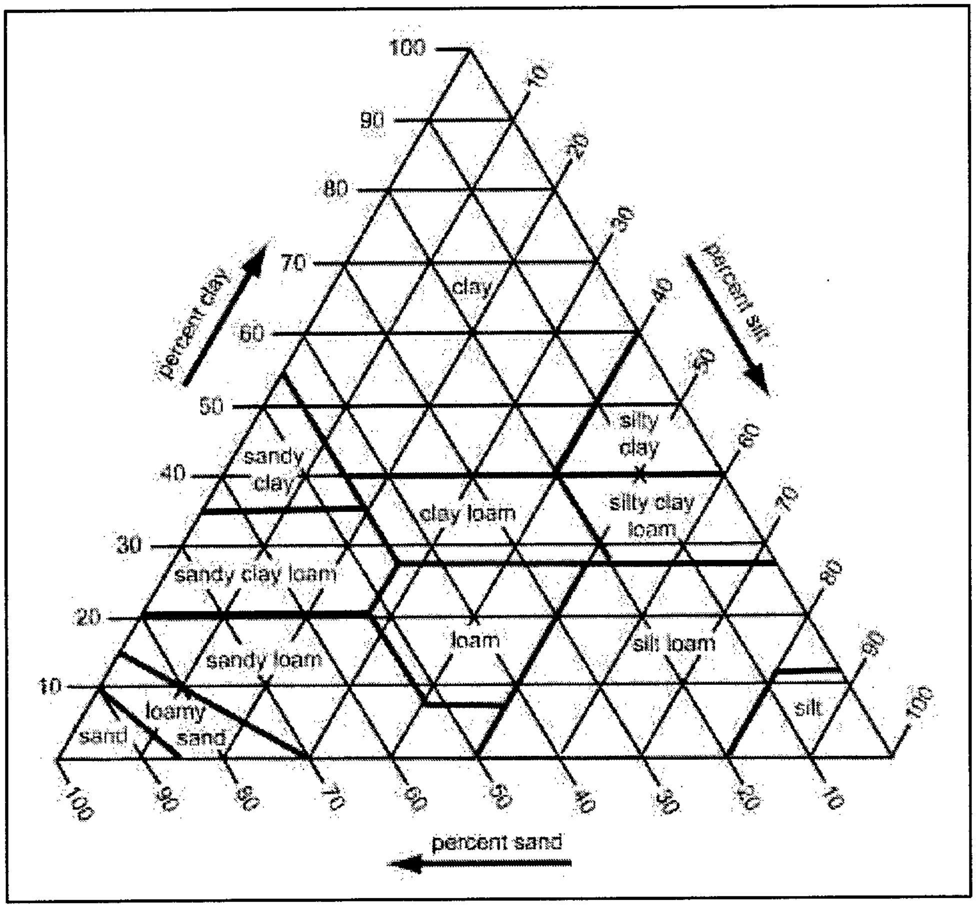

Figure 8. Chart showing the percentages of clay, silt, and sand in the basic soil textural classes and the corresponding soil textural name

Table 15
Soil Texture Table and Corresponding Variable Subindex Score

Soil Texture	Variable Subindex Score
Gravel	0.00
Sand	0.33
Loamy sand	0.42
Sandy loam	0.50
Sandy clay loam	0.58
Loam	0.67
Silt loam	0.75
Silt	0.83
Sandy clay	0.92
Clay loam	1.00
Silty clay loam	1.00
Silty clay	1.00
Clay	1.00

Depth of the O and A Soil Horizons (V_{O+A_HORIZ}). The characteristics of the soil surrounding and within the wetland have a profound effect on the rate and quantity of nutrient cycling in pothole wetlands. This variable is a measure of the depths of the O and A horizons across each vegetation community in the Low Prairie, Wet Meadow, Shallow Marsh, and Deep Marsh wetland zones.

V_{O+A_HORIZ} is quantified by direct measurement of the O and A soil horizon depths from soil pits or from soil cores and is calculated as a weighted mean depth based on the percent area of each of the vegetation communities measured within the four wetland zones.

The Variable Subindex Score for V_{O+A_HORIZ} is based on the relationship between the added depths of the O and A horizons and the Variable Subindex Score illustrated in Figure 9.

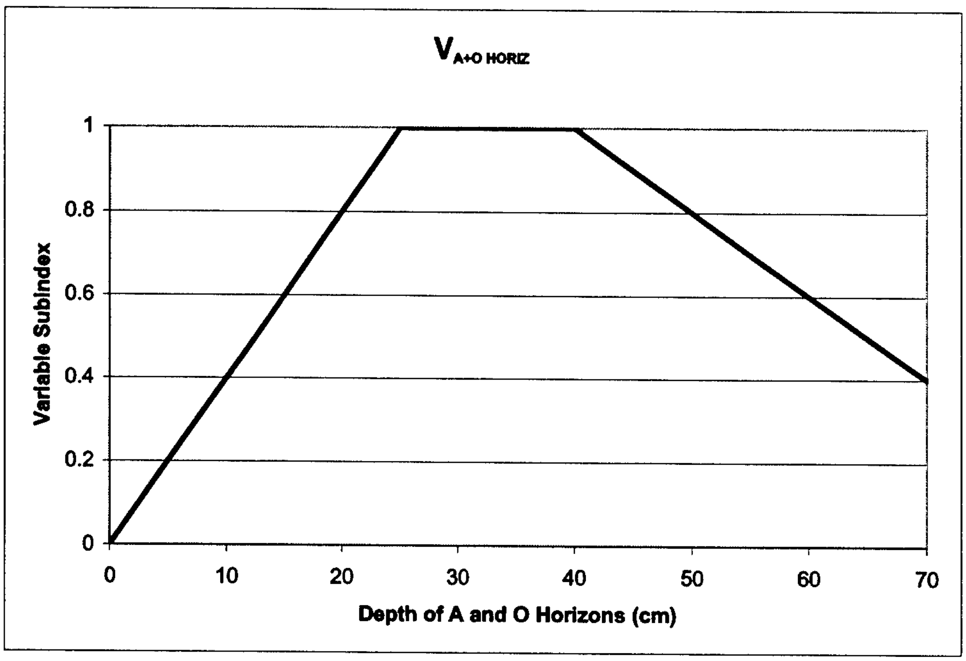

Figure 9. Relationship between O and A Horizon soil depths and the Variable Subindex Scores

Sediment Delivery (V_{SED}). The quantity of sediment entering a wetland or being redistributed within the wetland has a significant effect on nutrient cycling within the wetland. Sediments carry new nutrients to the wetland or, if nutrient poor, may bury organic material and thus largely remove it from the cycling process.

This variable represents the potential amount of sediment entering a pothole wetland as a product of erosion from adjacent uplands as well as including the various land uses within and surrounding the wetland.

The metrics of this variable are based on the Revised Universal Soil Loss Equation (RUSLE) (Soil Conservation Service (SCS)/NRCS), Renard et al. (1997), and Brady (1974):

$$RUSLE\_Index = R \times K \times L \times S \times C \times P \quad (3)$$

where

R = rainfall-runoff erosivity factor, which for this Reference Domain is 1.0 and therefore is not included in the index calculations for this Guidebook

K = soil erodibility factor of the adjacent upland. To obtain K, use the soil texture triangle (Figure 8) to determine the soil texture of the A horizon in the upland soils. Read the K erodibility factor of this soil from Table 16

L = mean slope length, ft, of four transects taken from the catchment boundary to the outer edge of the Low Prairie wetland zone

S = mean slope, percent, of the four transects = $h/l \times 100$

C = cover management factor

P = support practices factor

Table 16
Soil Texture, Geometric Mean Particle Size, and Corresponding K Erodibility Factor

Soil Texture	Log Mean Geometric Particle Diameter	K Erodibility Factor
Silty clay	-1.2	0.041
Silt	-1.0	0.034
Silty clay loam	-0.9	0.03
Clay	-0.7	0.02
Silt loam	-0.6	0.018
Clay loam	-0.5	0.014
Loam	-0.4	0.01
Sandy clay	-0.3	0.009
Sandy clay loam	-0.2	0.007
Sandy loam	-0.2	0.006
Loamy sand	-0.1	0.003
Sand	0.0	0.001

In this procedure CP is calculated as a single factor where

$$CP = \frac{1}{\sqrt{\left(\frac{(V_{UPUSE} + V_{EDGEUSE})}{2}\right) \times V_{WETUSE}}} \quad (4)$$

The Variable Subindex Score for V_{SED} is based on the relationship between RUSLE and the Variable Subindex Score described by the equation:

$$V_{SED}\text{ Variable Subindex} = -0.1561 \times \ln(RUSLE) + 0.5243 \qquad (5)$$

and illustrated in Figure 10.

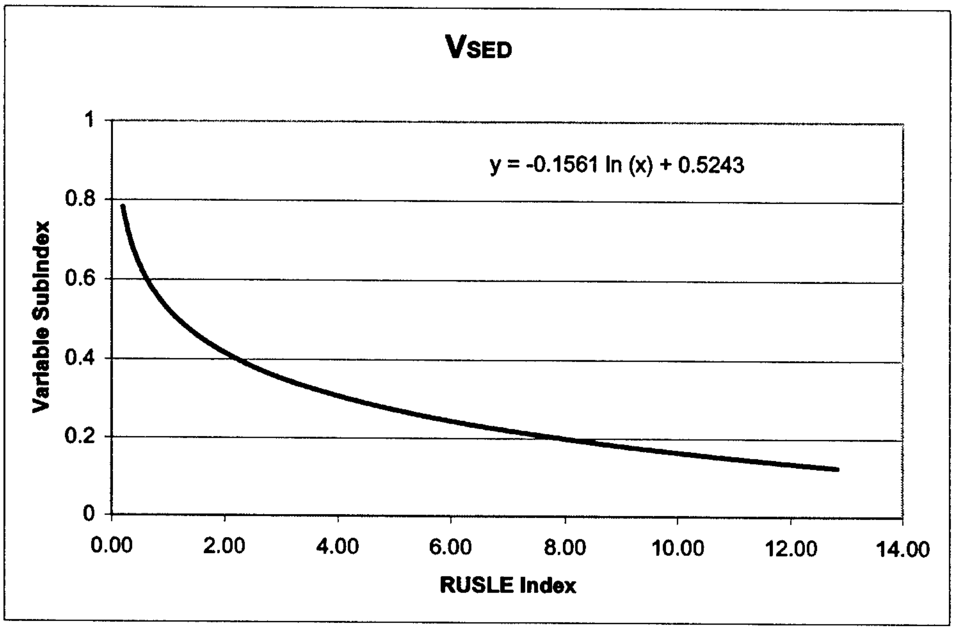

Figure 10. Relationship between RUSLE Index and Variable Subindex Score

Functional Capacity Index

The assessment model for calculating the FCI is as follows:

$$FCI = \left[\left(\frac{V_{WETUSE} + V_{EDGEUSE}}{2}\right) \times \left(\frac{V_{ORGDECOMP} + V_{O+A\_HORIZ} + V_{PORE} + V_{SED}}{4}\right)\right]^{1/2} \qquad (6)$$

In the model equation, the wetland function of Nutrient Cycling is dependent on the following variables: (a) land use within the wetland, (b) land use along the wetland edge, (c) organic matter decomposition measured within the wet meadow, (d) depth of the A and O horizons of the soil, (e) pore space of the soil of the C horizon in the wet meadow, and (f) rate of sediment transport to the wetland.

In the first subpart of the equation there are two variables dealing with landuse: V_{WETUSE} and $V_{EDGEUSE}$. These variables are weighted equally and averaged. In the second subpart of the equation are the variables $V_{ORGDECOMP}$, which is a measure of the accumulation of organic matter balanced with the rate of decomposition; V_{O+A_HORIZ}, which is a measure of the organic matter accumulation

within the soils over an extended time period; V_{PORE}, which is a measure of the porosity of the C horizon parent material underlying the wetland; and finally, V_{SED}, which is a measure of the rate of sediment transport to the wetland. These four variables are weighted equally and divided by 4. The FCI of this function is calculated by determining the geometric mean of the two subparts of the algorithm.

Function 3: Retention of Elements, Compounds, and Particulates

Definition

The function Retention of Dissolved Elements, Compounds, and Particulates is defined as the ability of the pothole wetland to remove permanently and/or sequester (temporarily immobilize) elements, compounds, and particulates that are imported to the wetland from adjacent upland and atmospheric sources. Elements include macronutrients essential to plant growth (primarily nitrogen and phosphorus), and heavy metals (e.g., arsenic, lead, zinc) that can be toxic to many life forms at high concentrations. Compounds include pesticides, oils, salts, and dissolved organic compounds. Particulates include geologic and accelerated erosional sediments and organic matter. Inputs commonly enter via surface and ground waters and/or precipitation. A potential independent quantitative measure of this function is the quantity of an individual element or compound retained per unit area for a specified period of time (e.g., $g/m^2/year$).

Rationale for selecting the function

Glacial pothole wetlands are located predominantly in geomorphologically closed depressional basins. Surface waters from adjacent uplands are concentrated into these wetlands due to basin topography. Surface waters carry elements, compounds, and particulates into the wetland that may be beneficial or detrimental to the functioning of the wetland (Mitsch and Gosselink 1993). There are two primary benefits of this function. First, the permanent removal and/or temporary immobilization of elements, compounds, and particulates reduces the load of nutrients, heavy metals, pesticides, sediments, and other pollutants into groundwater and nearby rivers and streams. Second, at natural sustainable levels these inputs are necessary for the overall maintenance of the nutrient budget and associated characteristic plant and animal communities of the wetland.

Characteristics and processes that influence the function

The characteristics and processes that influence the ability of a pothole wetland to perform this function can be divided into two groups. The first deals with the sources and mechanisms by which elements, compounds, and particulates are transported into the pothole wetland. Basin morphology and landscape

position of the wetland largely determine the source and mechanisms of transport. The second group of characteristics and processes relate to the removal and/or immobilization of the elements, compounds, and particulates that are transported into the wetland. Vegetation structure and the biogeochemical processes in wetland soils greatly influence the ability of the wetland to perform this function.

Sources and transportation. Elements, compounds, and particulates are transported into pothole wetlands from several sources: dry deposition and precipitation from the atmosphere; shallow groundwater flow; overland flow from adjacent uplands; and occasional overflows connecting wetlands during wet periods of high storage (Winter and Rosenberry 1995). Atmospheric inputs have been documented as having significant effects on some aquatic ecosystems (Stanford et al. 1994). Yet, atmospheric sources are assumed to account for a relatively small amount of the total quantity of elements, compounds, and particulates that typically impact pothole wetlands from a 404 perspective.

Goundwater sources and mechanisms. LaBaugh, Winter, and Rosenberry (1998) (also see *Great Plains Research* 8, 1998) provide an overview of the relationship between hydrologic processes in Prairie Pothole Wetlands and the chemical and biological characteristics. These examples are from the glaciated prairie, not the intermountain west, yet are consistent with the reference data collected for this Guidebook. Their examples describe the general hydrologic processes common to many physiographic settings in which closed-basin wetlands are found (Winter 1988).

Hubbard (1988) studied the inputs and outputs of elements and compounds from shallow groundwater in glaciated prairie wetlands. He found correlation between the hydrological regime of the wetland (i.e., as a recharge, discharge, or flow-through wetland largely determined by landscape position), soil and water chemistry, and soil morphology. Typical groundwater recharge prairie wetlands are temporary to seasonal wetlands with very low electrical conductivities and noncalcareous and nonsaline soils and have very deep soil with eluvial or argillic horizons. In contrast, typical groundwater discharge prairie wetlands are semipermanent to permanent wetlands and have the highest electrical conductivities, calcareous and saline soils, and the least developed sola. Typical flow-through prairie wetlands vary from seasonal to permanent and are intermediate in electrical conductivity, salinity, carbonate concentrations, and soil morphology. These correlations suggest that the hydrologic regime of a prairie wetland affects the biogeochemical processes within the wetland. These correlations also support assumptions that wetland soils provide the best available indicators of the average long-term biogeochemical processes and groundwater flow patterns for depressional wetlands. However, further research is needed to determine if these soil and water chemistry and soil morphological differences have a significant effect on wetland functions of glaciated prairie wetlands having different hydrological regimes.

Surface water sources and mechanisms. The dominant mechanisms for the input and output of elements, compounds, and particulates among pothole wetlands are surface sources such as overland flow, surface connections between

wetlands during wet periods, and man-made ditches. These sources are a function of wetland basin morphology (e.g., catchment size, slope gradient, and natural or man-made surface connections). With all other characteristics constant, larger catchments have a greater source area from which inputs may come, a greater concentration of overland flows, and hence greater inputs (Brady 1974). Similarly, overland flow on steeper slopes is more likely to run off than infiltrate, and thus will have greater velocity and erosive power. Theoretically, if other characteristics are held constant, a doubling of overland flow velocity enables the water to move particulates 64 times larger, allows it to carry 32 times more material in suspension, and increases the erosive power by a factor of 4 (Brady 1984).

Surface water connections between pothole wetlands or between a pothole wetland and any other wetland or water body do not typically occur naturally. Exceptions are during wet periods with high storage and by man-made ditching or tiling. Yet, no local or regional studies document the transport of elements, compounds, and particulates by surface water connections between pothole wetlands and any other wetland or water body. However, flood attenuation by palustrine wetlands adjacent to riverine systems is well documented in the literature (Sather and Smith 1984), and wetland drainage can increase watershed discharges and flooding (Hubbard 1988). Further, it is known that surface waters carry either dissolved or particulate forms of elements, compounds, and sediments. Therefore, it is assumed that a pothole wetland that is drained (ditched or tilled) will not be able to remove or immobilize elements, compounds and particulates as it would had it not been drained.

Dense vegetation cover reduces surface water velocities and allows for greater infiltration, filtration of particulates, and soils less likely to erode. Therefore, uplands with dense vegetation cover will supply fewer elements, compounds, and particulate inputs to the wetland than uplands with sparse vegetation cover.

Removal and Immobilization. Note that every element, chemical compound, nutrient, or heavy metal will have its own biogeochemical pathway once it enters a pothole wetland. For simplicity, this discussion will be limited to the fates of the two most commonly occurring and studied elements known to enter wetlands in surface waters: nitrogen and phosphorus. For more thorough reviews see Mausbauch and Richardson (1994), Mitsch and Gosselink (1993), and Hubbard (1988).

Most pothole wetlands only occasionally, if ever, overflow. Thus, any nitrogen and phosphorus that enter a pothole wetland are largely taken up by plants, permanently retained, or sequestered through a variety of biogeochemical processes occurring within wetland soils. However, some losses to groundwater seepage, animal export, or as gas to the atmosphere can occur. None of these losses has been studied in intermontane pothole wetlands. Traditionally, animal exports from wetlands have been considered minor but are poorly understood (Mitsch and Gosselink 1993). All other losses (to the atmosphere or groundwater), removals, and immobilizations are largely dependent upon the process of reduction as a result of inundation and subsequent anoxic or anaerobic conditions.

Maximum losses of nitrogen to the atmosphere through denitrification occur where soil moisture contents fluctuate repeatedly (Patrick and Mahapatra 1968; Ponnamperuma 1972; and Reddy and Patrick 1975). Within a pothole wetland, this is most likely the Wet Meadow zone. Phosphorus is not lost to the atmosphere. Losses by seepage to groundwater are possible for both nitrogen (nitrate, NO_3^-) and phosphorus (P), because both become soluble relatively soon after inundation (i.e., at relatively high redox potentials). However, groundwater seepage rates are thought to be low. Further, both are in available forms for plant uptake and must pass the root zone of the hydrophytic vegetation. Nitrate must also avoid assimilation by denitrifing bacteria, and phosphorus has a high electrical affinity for clay minerals at alkaline pH values (most pothole wetlands soils have high clay contents and alkaline pH values). Another form of nitrogen commonly occurring in wetlands is ammonium (NH_4^+). Ammonium is the first inorganic nitrogen compound released during decomposition of organic matter. It is thought to build up and be the only form of nitrogen available to plant in permanently anaerobic soils because of the lack of aerobic bacteria (Ponnamperuma 1972). Like phosphorus and nitrate, ammonium is available for plant uptake and must escape the root zone to be lost to groundwater seepage. However, as with nitrate and phosphorus, seepage to groundwater is most probable during early spring before vascular plant activity becomes high, and in the fall (before winter freezing) when vascular plants are dormant. Prairie wetlands with cultivated (sparse vegetation cover) catchments accumulated sediments at a significantly higher rate than did basins with dense grassland cover.

Description of model variables

Upland Land Use (V_{UPUSE}). This variable is a function of the various land uses in the upland above the outer edge of the wetland, generally characterized by the Low Prairie wetland zone. If the catchment boundary is extremely large or indistinct, then a perimeter of 100 m from the wetland edge is used as the functional upland zone of influence.

Land use in the upland surrounding the wetland has direct bearing on the movement of material to the wetland and the accumulation of those materials. Several examples of this are available ranging from the input of particulates associated with cultivation of the upland and the movement of soil downslope to the wetland to runoff from commercial right-of-ways such as roads and parking lots.

The calculation of this variable is based on the general land use of the upland over an extended period of time (i.e., past 10–20 years). This is referred to as the Catchment Land Use and is distinguished by the land use descriptions and scores in Table 17.

Table 17
Current Land Use Treatment in the Upland and Corresponding Variable Subindex Score

Current Land Use Treatment	Score
Commercial right-of-way or paved driveway	0.00
Private right-of-way or unpaved driveway	0.10
Heavy grazing by livestock	0.20
Annual crop production	0.20
Generalized soil disturbance	0.30
Residential or commercial lawn	0.40
Moderate grazing by livestock	0.50
Mowed and hayed, but uncultivated field	0.60
Light grazing by livestock	0.70
Conservation easement with planting	0.85
Fallow, no cultivation or livestock >2 years, but <10 years	0.90
Managed as undisturbed grassland >10 years, but < 20 years	0.95
Managed as undisturbed grassland > 20 years	1.00

Land Use in the Wetland Edge ($V_{EDGEUSE}$). This variable is a function of the various land uses along the edge of the wetland. This area is generally categorized as the Low Prairie wetland zone (Stewart and Kantrud 1972). If the Low Prairie is indistinct, then $V_{EDGEUSE}$ is based on the area above the Wet Meadow wetland zone to a distance of 25 m.

Land use along the wetland edge affects the movement of particulates as well as other elements and compounds to the wetland. For example, tilling of the soil within this buffer zone along the wetland edge greatly increases the movement of surface soil to the wetland.

The calculation of this variable is based on the general land use within the Low Prairie surrounding the wetland over an extended period of time (i.e., past 10–20 years). This is referred to as the Wetland Edge (Low Prairie) Land Use and is distinguished by the land use descriptions and scores found in Table 18.

Land Use in the Wetland (V_{WETUSE}). This variable is a function of the various land uses within the wetland. For this Guidebook, this area is categorized as the Wet Meadow, Shallow Marsh, and Deep Marsh wetland zones (Stewart and Kantrud 1972). There is considerable hydrogeomorphic variability among wetlands within this HGM class. Intermittent and temporary wetlands may possess only a Wet Meadow wetland zone to the center of the wetland, whereas semipermanent and permanent wetlands may possess a Wet Meadow, Shallow Marsh, and Deep Marsh.

Table 18
Current Land Use Treatment in the Low Prairie Wetland Zone and Corresponding Variable Subindex Score

Land Use Treatment	Score
Current Use	
Heavy grazing by livestock	0.20
Annual crop production	0.20
Generalized soil disturbance	0.30
Residential or commercial lawn	0.40
Moderate grazing by livestock	0.50
Mowed and hayed, but uncultivated field	0.60
Light grazing by livestock	0.70
Conservation easement with planting	0.85
Fallow, no cultivation or livestock >2 years, but <10 years	0.90
Managed as undisturbed grassland >10 years, but <20 years	0.95
Managed as undisturbed grassland >20 years	1.00
Projected Use	
Fill with paving	0.00
Fill without paving	0.05
Partial fill	0.10

Different land uses within the wetland affect the wetland in different ways. Cattle grazing has a marked effect on the redistribution of sediments and thus the ability of those sediments to retain elements and compounds.

The calculation of this variable is based on the general land use within the Wet Meadow, Shallow Marsh, and Deep Marsh over an extended period of time (i.e., past 10–20 years). Land use within these three wetland zones is referred to as V_{WETUSE} and is distinguished by the land use descriptions and scores presented in Table 19.

Sediment Delivery (V_{SED}). The quantity of sediment entering a wetland or being redistributed within the wetland has a significant effect on retention of particulates, elements, and compounds within the wetland. Sediments carry a variety of materials to the wetland.

This variable represents the potential amount of sediment entering a pothole wetland as a product of erosion from adjacent uplands as well as including the various land uses within and surrounding the wetland.

Table 19
Current Land Use Treatment in the Wet Meadow, Shallow Marsh, and Deep Marsh Wetland Zones and Corresponding Variable Subindex Score

Land Use Treatment	Score
Current Use	
Heavy grazing by livestock	0.20
Annual crop production	0.20
Generalized soil disturbance	0.30
Residential or commercial lawn	0.40
Moderate grazing by livestock	0.50
Mowed and hayed, but uncultivated field	0.60
Light grazing by livestock	0.70
Conservation easement with planting	0.85
Fallow, no cultivation or livestock >2 years, but <10 years	0.90
Managed as undisturbed grassland >10 years, but <20 years	0.95
Managed as undisturbed grassland >20 years	1.00
Projected Use	
Fill with paving	0.00
Fill without paving	0.05
Partial fill	0.10

The metrics of this variable are based on the RUSLE.

$$RUSLE\_Index = R \times K \times L \times S \times C \times P \tag{7}$$

where

R = rainfall-runoff erosivity factor, which for this Reference Domain is 1.0 and therefore is not included in the index calculations for this Guidebook

K = soil erodibility factor of the adjacent upland. To obtain K, use the soil texture triangle (Figure 11) to determine the soil texture of the A horizon in the upland soils. Read the K erodibility factor of this soil from Table 20

L = mean slope length, ft, of four transects taken from the catchment boundary to the outer edge of the Low Prairie wetland zone

S = mean slope, percent, of the four transects = $h/l \times 100$

C = cover management factor

P = support practices factor

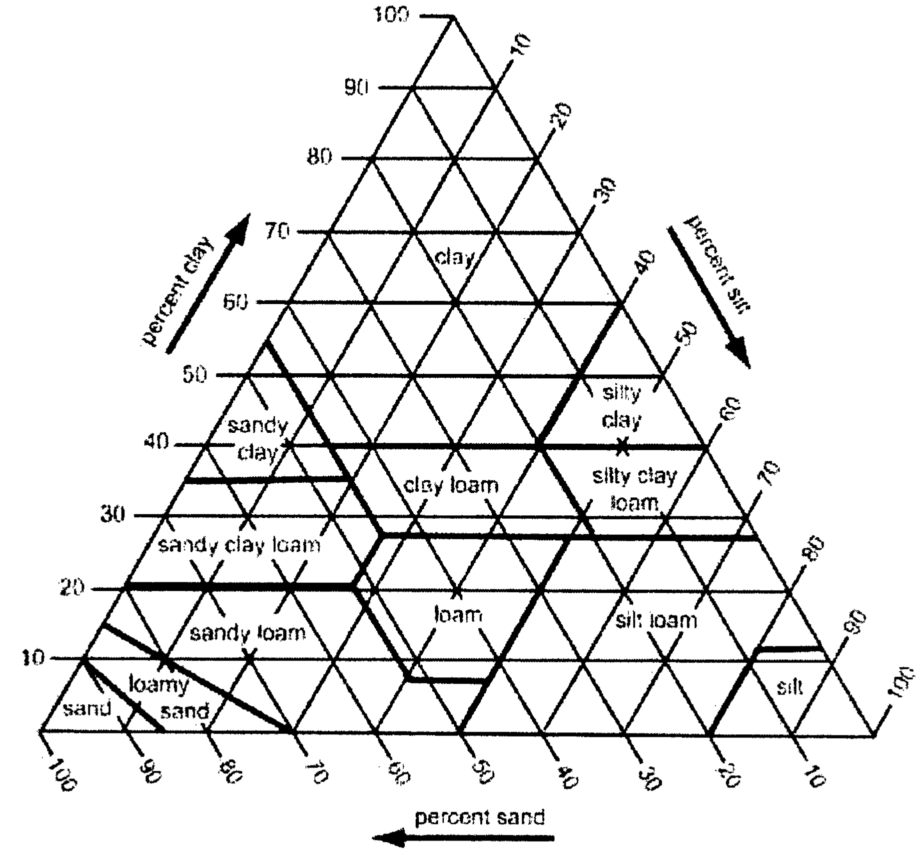

Figure 11. Chart showing the percentages of clay, silt, and sand in the basic soil textural classes and the corresponding soil textural names

Table 20
Soil Texture, Geometric Mean Particle Size, and Corresponding K Erodibility Factor

Soil Texture	Log Mean Geometric Particle Diameter	K Erodibility Factor
Silty clay	-1.2	0.041
Silt	-1.0	0.034
Silty clay loam	-0.9	0.03
Clay	-0.7	0.02
Silt loam	-0.6	0.018
Clay loam	-0.5	0.014
Loam	-0.4	0.01
Sandy clay	-0.3	0.009
Sandy clay loam	-0.2	0.007
Sandy loam	-0.2	0.006
Loamy sand	-0.1	0.003
Sand	0.0	0.001

In this procedure, CP is calculated as a single factor where

$$CP = \frac{1}{\sqrt{\left(\frac{(V_{UPUSE} + V_{EDGEUSE})}{2}\right) \times V_{WETUSE}}} \tag{8}$$

The Variable Subindex Score for V_{SED} is based on the relationship between the RUSLE and the Variable Subindex Score, described by Equation 4,

$$V_{SED} \text{ Variable Subindex} = -0.1561 \times \ln(RUSLE) + 0.5243 \tag{9}$$

and illustrated in Figure 12.

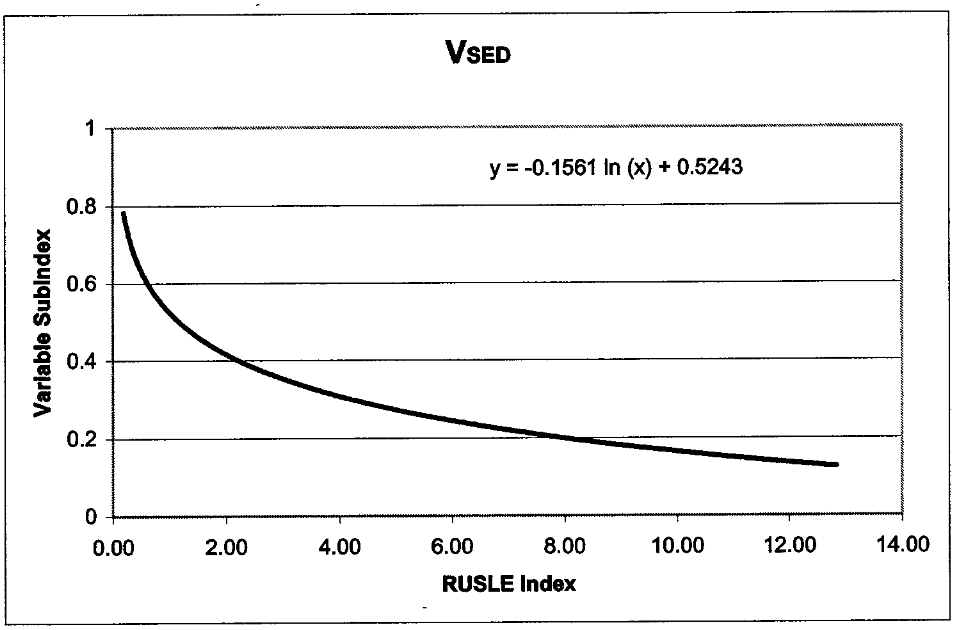

Figure 12. Relationship between RUSLE Index and the Variable Subindex Score

Depth of the O and A Soil Horizons (V_{O+A_HORIZ}). This variable represents the weighted mean depth of the O and A soil horizons across each of the vegetation communities in the Low Prairie, Wet Meadow, Shallow Marsh, and Deep Marsh wetland zones. V_{O+A_HORIZ} is quantified by direct measurement of the O and A soil horizon depths from soil pits or from soil cores.

The Variable Subindex Score for V_{O+A_HORIZ} is based on the relationship between the added depth of the O horizon and the A horizon and the Variable Subindex Score illustrated in Figure 13.

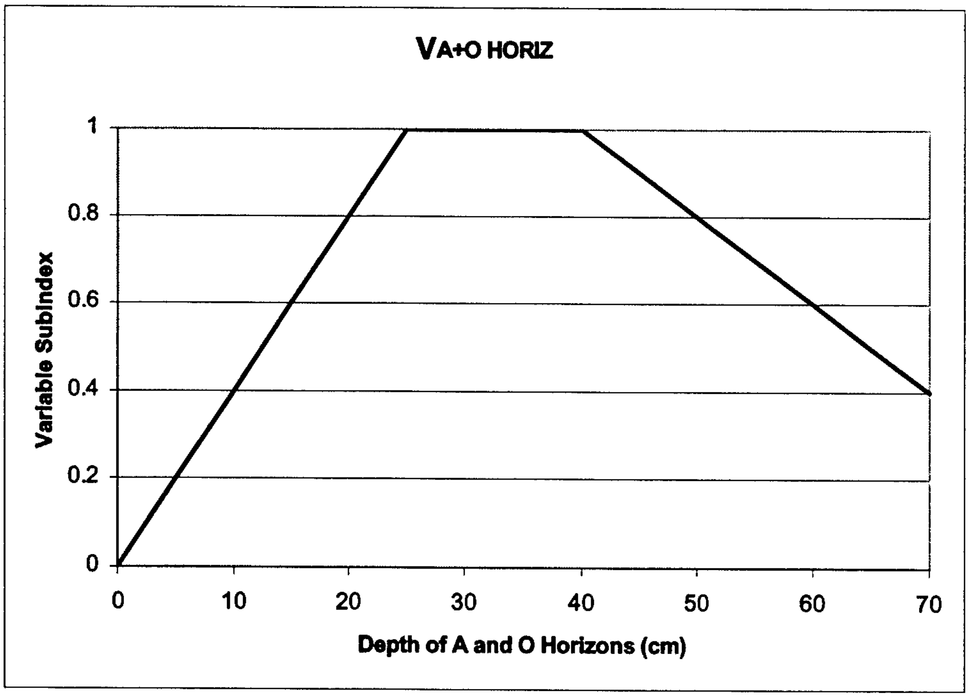

Figure 13. Relationship between O + A Horizon soil depths and the Variable Subindex Scores

Decomposition of Organic Matter (*$V_{ORGDECOMP}$*). This variable represents the long-term store of organic matter and nutrients. It is also an indicator of the characteristic decomposer community of the wetland. The soil O horizon is composed largely of organic materials derived from dead plant tissue and to a lesser extent animals. What were originally plants and animals are residues at various stages of decomposition; hence, they are both a nutrient store and source for the wetland. Departures in the depth of the O horizon from reference standards are indicators of too little or too much organic nutrient additions to the wetland or too fast or too slow a rate of decomposition, based on reference standard. Too few or too many nutrient additions or significant departures from reference standards of decomposition rates will interfere with the sustainability of the wetland to perform this function.

The soil A horizon is a surface mineral soil characterized by the accumulation of humus. Humus is black, highly decomposed, and naturally colloidal (i.e., has a small particle size, large surface area, and net negative charge). Its ability to hold nutrients is greater than that of any other soil constituent. The depth and color of the A horizon are indexes of the ability of the soil to store nutrients for plant availability. Departures from reference standards are indicators of changes in long-term organic matter inputs. A thin, lightly colored A horizon may be the result of lowered productivity caused by management. An A horizon having a thickness greater than reference standard is likely the result of accelerated erosion from adjacent uplands. $V_{ORGDECOMP}$ is calculated as an Organic Matter Decomposition Factor based on the Munsell Soil Color Chart chroma and hue of the A horizon in the Wet Meadow wetland zone and the added depths (cm) of the

A and O horizons, also in the Wet Meadow. The Organic Matter Decomposition Factor is calculated as

$$OMDF = \left[\frac{(ChromaA \times HueA \times DepthA)}{10} + DepthO \right] \tag{10}$$

The Variable Subindex Score for $V_{ORGDECOMP}$ is based on the relationship between the Organic Matter Decomposition Factor and the Variable Subindex Score illustrated in Figure 14.

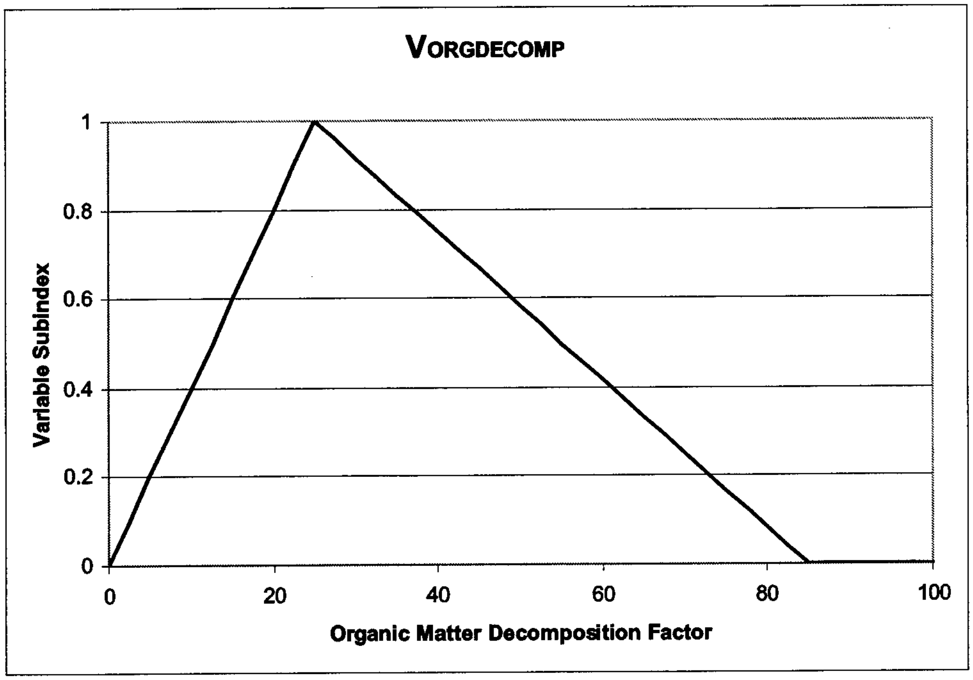

Figure 14. Correlation between Organic Matter Decomposition Factor and the Variable Subindex Score

Functional Capacity Index

The assessment model for calculating the functional capacity index is as follows:

$$FCI = \left\{ \left[\frac{(V_{UPUSE} + V_{EDGEUSE} + V_{WETUSE})}{3} \right] \times \left[\frac{(V_{SED} + V_{O+A\_HORIZ} + V_{ORGDECOMP})}{3} \right] \right\}^{1/2} \tag{11}$$

In the model equation for the removal of elements, compounds, and particulates the algorithm appears in two subparts; the first is related to land uses in the catchment and wetland, and the second is related to the accumulation of materials in the soil. Please note that this function can be easily misinterpreted in that a particular wetland may have an unnaturally high accumulation rate of sediment that overextends the capacity of the wetland to sustain the function or act in equilibrium with other functions. More is not necessarily better.

The first subpart of the equation contains three variables dealing with land use: V_{UPUSE}, $V_{EDGEUSE}$, and V_{WETUSE}. These variables are weighted equally and averaged. In the second subpart of the equation are the variables V_{SED}, V_{O+A_HORIZ}, and $V_{ORGDECOMP}$. These variables are a measure of the accumulation of inorganic and organic materials. To calculate the FCI of this function, determine the geometric mean of the two subparts of the algorithm.

Function 4: Maintain Characteristic Plant Community

Definition

The function Maintain Characteristic Plant Community is defined as the capacity of an intermontane prairie pothole wetland to possess and sustain a native plant community that is appropriate for specific unaltered environmental conditions and hydrogeomorphic characteristics. A characteristic plant community is maintained by heterogeneity of environmental conditions, especially geomorphology, water regime, natural disturbances, and water/soil chemistry. A characteristic plant community also requires the maintenance of vegetative properties such as seed dispersal, vegetative propagules, density, and growth rates that permit response to natural variation in climate and disturbance (e.g., fire, herbivory). Invasion by nonnative plants or uncharacteristic native species is an indication that this function has been diminished. Potential independent, quantitative measures for validating the functional index include species composition, coverage, and plant density.

Rationale for selecting the function

An array of wetland processes, characteristics, and functions are significantly affected by the maintenance of a characteristic plant community. Vegetation represents the majority of standing biomass in most intermontane pothole wetlands. Emergent macrophytic vegetation provides most of the vegetative standing crop, conducts most of the wetland primary production and nutrient cycling, and contributes most of the biomass to annual detrital accumulations and soil development. Macrophytic vegetation also provides most of the trophic support for secondary production, whether that production is based on direct grazing of living plant biomass or whether the energy is shunted through the detrital-based food web. Vegetation also provides the habitat structure necessary

for nesting, resting, and cover for many animal species. Thus, a characteristic plant community is necessary to maintain local and regional diversity of animals.

A characteristic plant community is one that remains within a natural range of variation in production, coverage, and diversity and is composed primarily of native species. Clearly, a plant community that is dominated by nonnative species does not qualify as being "characteristic" of an undisturbed state. Indeed, invasion by nonnative plants is known to alter ecosystem processes, causing both structural and functional change in the vegetative community (D'antonio and Vitousek 1992). Vitousek (1990) discusses ways that plant invasions can alter ecosystem processes, including whole-system fluxes and rates of resource supply. Examples of species invasions significantly changing ecosystem structure and function include *Tamarix* spp. in the southwestern United States and Australia (Griffin et al. 1989; Loope et al. 1988; Neill 1983), ice-plants (*Mesembryanthemum crystallinum* and *Carpobrotus edulis*) in California and Australia (Kloot 1983; Vivrette and Muller 1977; D'antonio 1990), and the nitrogen-fixer *Myrica faya*, which invades and dominates nitrogen-limited areas and increases inputs and availibility (Vitousek et al. 1987; Vitousek and Walker 1989). Likewise, invading species can alter the disturbance regime (e.g., type, frequency, intensity) of an ecosystem. For example, a change in community characteristics can significantly alter fire frequency and intensity (MacDonald and Frame 1988; Smith and Tunison 1992; van Wilgen and Richardson 1985).

The goal of assessing this function is to evaluate plant species composition and community structure and to determine current conditions and community successional patterns and status. There are inherent problems associated with properly assessing this function, even though there is a rich literature base that has been directed toward plant community dynamics. These problems are twofold: first, vegetation is dynamic, responding to natural variation and anthropogenic influence. Secondly, many wetland species are strongly influenced by periodic disturbances, such as fire, that reset successional patterns. Recognizing that vegetation is dynamic, but often operating on long-term responses to changing environmental conditions, one should take the approach of combining direct measures of vegetation characteristics and measures of environmental factors. Thus, to develop the appropriate Index of Function, one must consider land use practices and water regimes, in addition to vegetative characterization.

Characteristics and processes that influence the function

A characteristic plant community is maintained by a variety of biophysical variables. Several gradients influence the distribution and abundance of plant species in pothole wetlands. For example, vegetation patterns in Wet Meadows are significantly different from those in the Shallow Marsh habitat (Weller 1988; Kantrud, Krapu, and Swanson 1989). Not surprisingly, numerous studies have found that depth of water strongly influences vegetation patterns (Mitsch and Gosselink 1993). Likewise, the chemistry of water has a marked effect on nutrient availability and thus on plant species composition. The changing environmental gradients lead to vegetation patterns that are highly variable within and between wetlands (Cook 2001).

Wetlands are characterized, in part, by the vegetation that grows in them. Vegetation growing in the wetland accounts for the vast majority of the organic matter supply to the wetland that supports higher trophic levels. The higher trophic levels, in turn, influence the structure of the wetland vegetative community through herbivory and decomposition of detrital biomass. Thus, vegetation is also the primary source of organic matter that fuels the detrital-microbial decomposition process. Vegetation is significantly affected by other wetland ecosystem functions associated with hydrology (e.g., evapotranspiration, surface roughness) and nutrient cycling (e.g., nitrogen and phosphorus). Thus, wetland vegetation is an interactive component of wetland ecosystem structure and function, operating both as a response variable to driving mechanisms (e.g., landscape position, hydrologic regime, diversity), as well as a driving mechanism for other wetland functions (e.g., nesting habitat, primary productivity). Wetland vegetation should not be considered as temporally static, but rather as changing in composition and characteristics over a hierarchy of temporal scales: annual cycles, multiyear life history cycles, and longer climatic cycles (van der Valk 1981).

Description of model variables

Plant Density (V_{PDEN}). This variable represents the weighted mean density in stems/m^2 of plants within each of the vegetation communities in the Low Prairie, Wet Meadow, Shallow Marsh, and Deep Marsh. The vegetation in glacial pothole wetlands often appears as concentric rings around the wetland. These rings of vegetation generally coincide with hydrologic variation and have been described extensively in the literature, particularly regarding the Prairie Pothole Region (sensu Stewart and Kantrud 1972; Mitsch and Gosselink 1993).

The Variable Subindex Score for V_{PDEN}, illustrated in Figure 15, is based on the relationship between the Weighted Plant Density and the algorithm:

$$\text{Variable Subindex} = 0.1946 \ln(\boldsymbol{WPD}) - 0.7548 \qquad (12)$$

The weighted mean plant density is determined by a series of vegetation plots taken within each vegetation community. The mean plant density from each vegetation community is multiplied by the percent area of the whole wetland occupied by that community. The proportional plant densities of each vegetation community are added to obtain the Weighted Plant Density across the entire wetland.

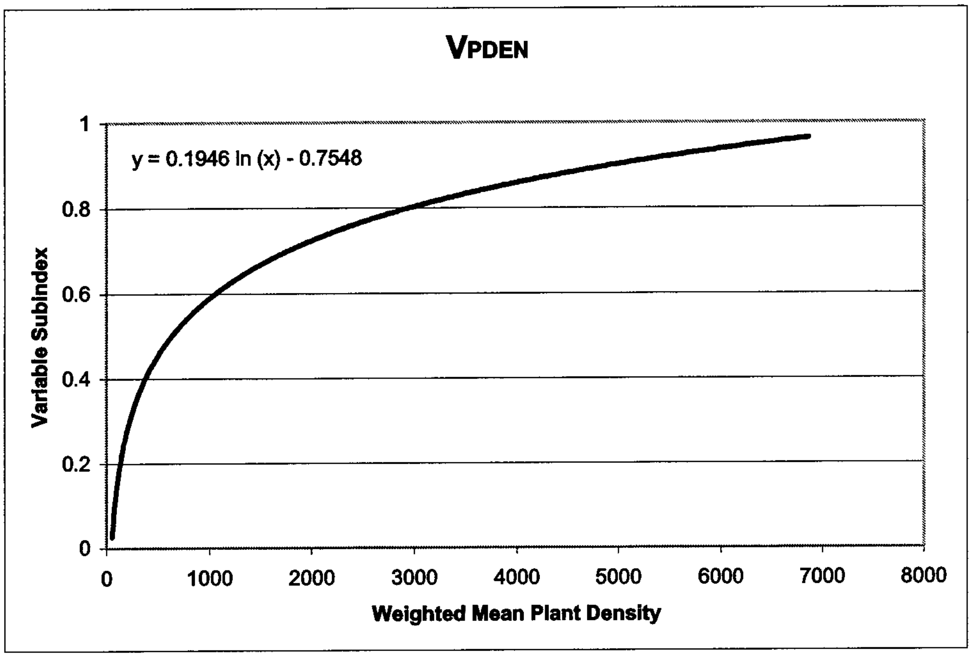

Figure 15. Correlation between Weighted Plant Density and the Variable Subindex Score

Percent Native Plant Diversity (V_{NPDIV}). This variable represents the percent diversity of native plants within the wetland (i.e., below the Upland/Low Prairie boundary). Native plant diversity is important to maintaining ecosystem structure and function. Rates of processes (e.g., elemental cycling, detritus accumulation), depend on native plants as well as animal populations, which are adapted to native plants for food, cover, or nesting. Nonnative plants alter the natural physical structure characteristic of a native community and are often indicators of unnatural levels of disturbance. For example, canary grass (*Phalaris arundinacea*) is a nonnative that commonly occurs in the Wet Meadow habitat type of the Intermontane Prairie Potholes where an unnaturally high rate of sedimentation has been entering the wetland from upland land use, such as cultivation.

This variable is a comparison of the native to nonnative species complex. The weighted mean plant density is determined by a series of vegetation plots taken within each vegetation community. The mean native plant diversity is determined for each vegetation community and is multiplied by the percent area in which the vegetation type occurs as a percentage of the whole wetland occupied by that community.

The plant diversity of each vegetation community is added to obtain the Weighted Plant Diversity across the entire wetland. V_{NPDIV} is measured as the weighted average percent native species (NS) across all vegetation communities in each of the wetland zones: Low Prairie, Wet Meadow, Shallow Marsh, and Deep Marsh. This value is then scaled to give the Variable Subindex Score based on the following regression equation and illustrated in Figure 16.

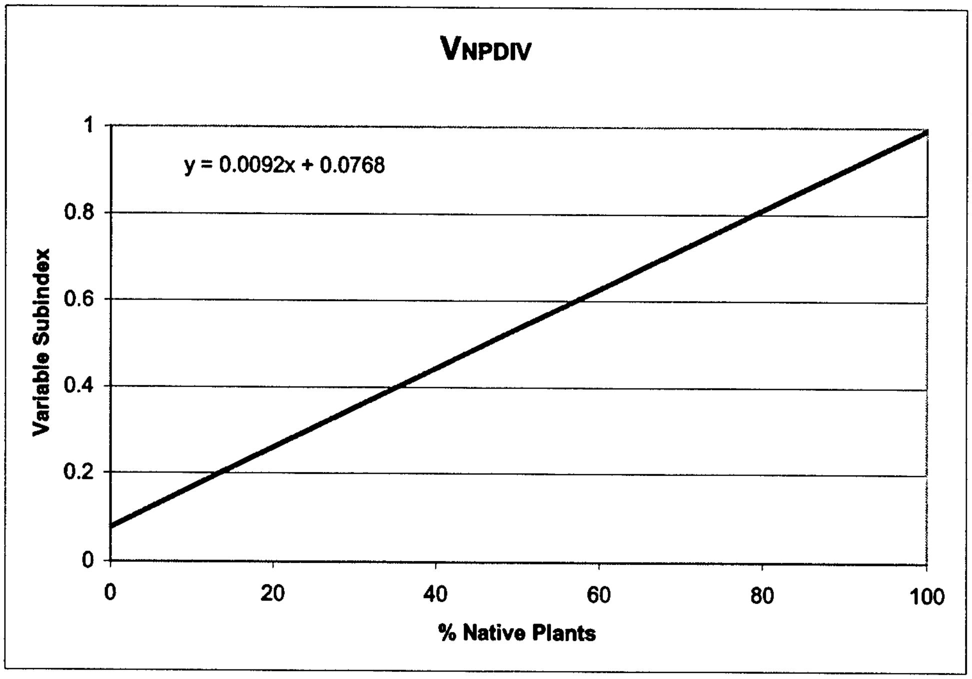

Figure 16. Correlation between Percent Native Plants and the Variable Subindex Score

$$\text{Variable Subindex} = 0.0092\ (\%NS) + 0.0768 \qquad (13)$$

Percent Coverage by Native Plants (V_{NPCOV}). This variable represents the weighted mean percent coverage of native plants within each of the vegetation communities of the wetland. Similar in concept and calculation to the variable V_{PDEN}, V_{NPCOV} is a measure of the percent coverage by native plants across the wetland. This variable is quantified by estimating the percent coverage within each community by native plants.

Native plant coverage is important to maintaining ecosystem structure and function. Rates of processes (e.g., elemental cycling, detritus accumulation) depend on native plants, as well as animal populations, which are adapted to native plants for food, cover, and nesting. Nonnative plants alter the natural physical structure that is characteristic of a native community and are often indicators of unnatural levels of disturbance.

The correlation between percent native plant coverage and the variable subindex among the reference wetlands is described by the following regression equation and illustrated in Figure 17:

$$\text{Variable Subindex} = y = 0.0076\ (\boldsymbol{WNPC}) + 0.2166 \qquad (14)$$

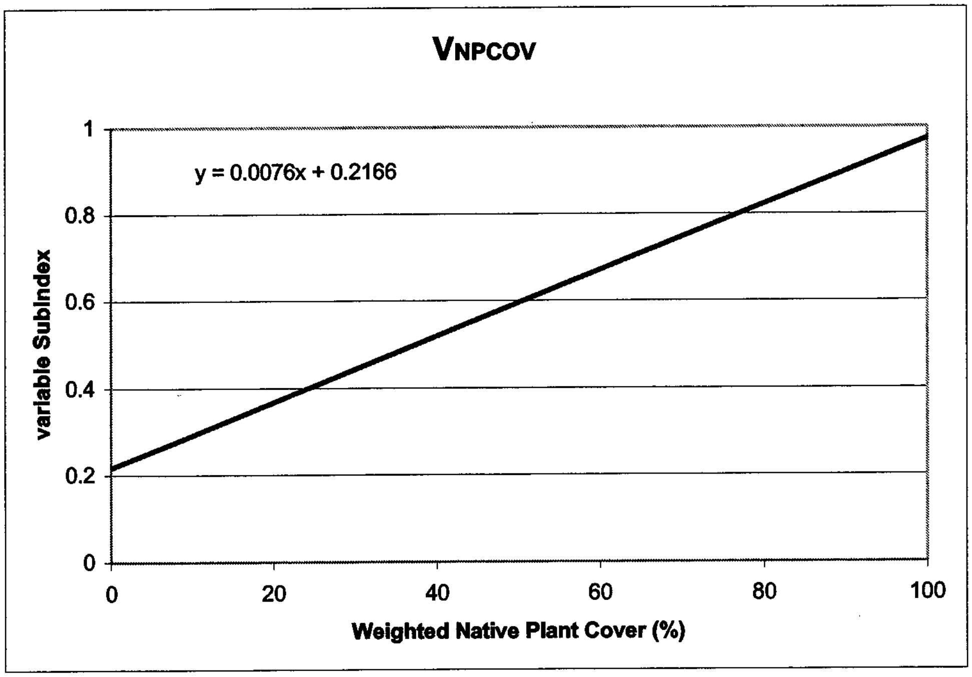

Figure 17. Correlation between percent Native Plant Cover and the Variable Subindex Score

Plant α-diversity across Wetland Zones ($V_{\alpha DIV}$). This variable is a measure of the α-diversity of plant species across each vegetation community and wetland zone. Reference standard wetlands in the Intermontane Glacial Pothole reference domain have numerous species distributed across multiple habitat types. Typically, the Low Prairie has the greatest species diversity, followed by the Wet Meadow and then the Shallow and Deep Marshes. For analyses on these pothole wetlands, this variable is measured as the weighted average Variable Subindex Score, where the Low Prairie, Wet Meadow, and the two marsh types of wetland zones have independent regression relationships.

The correlation between α-diversity and the variable subindex for the three wetland zones and across the reference wetlands is described by the following three regression equations and illustrated in Figure 18:

$$\text{Low Prairie Subindex} = 0.2431 \times \ln(\alpha\text{-diversity}) + 0.6483 \qquad (15)$$

$$\text{Wet Meadow Subindex} = 0.2087 \times \ln(\alpha\text{-diversity}) + 0.5943 \qquad (16)$$

$$\text{Shallow and Deep Marsh} = 0.203 \times \ln(\alpha\text{-diversity}) + 0.4984 \qquad (17)$$

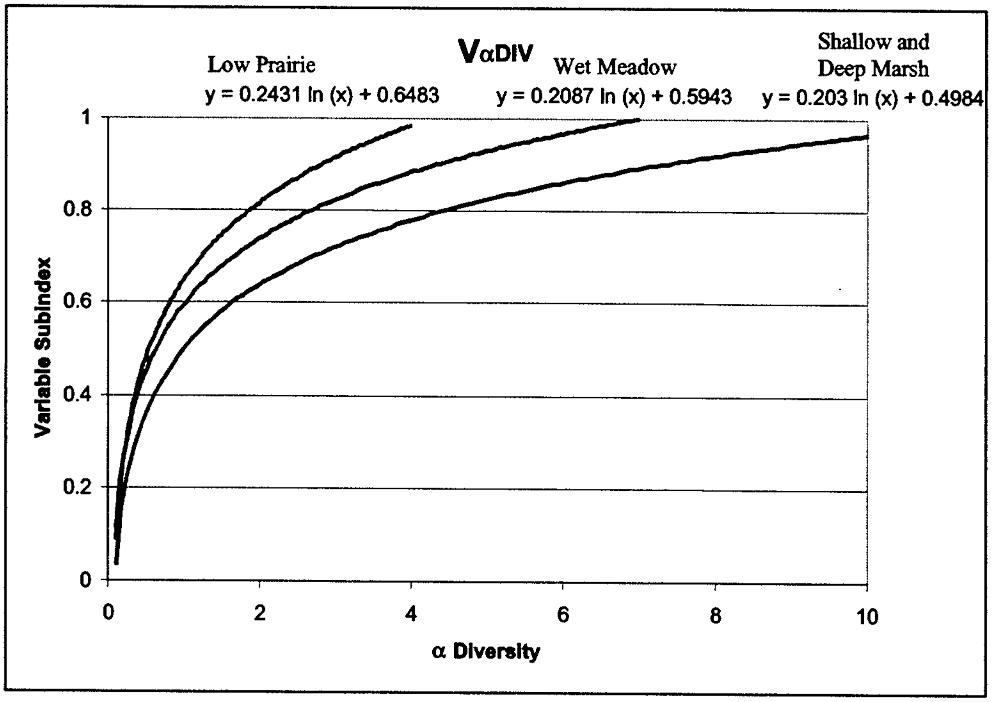

Figure 18. Correlation between α-diversity and the Variable Subindex Score

Hydrologic Modification ($V_{HYDROMOD}$). This variable represents the change in duration of flooding within the wetland expressed as the number of weeks in the year that ponded water is present. This variable is based on the duration of flooding (i.e., water regime) in a typical water year, since water storage can be significantly less following long-term drought or greatly extended following a long wet period. If possible, this variable should be evaluated directly by observation at the wetland site. If this is not possible, then indicators may be used to estimate the number of weeks of inundation during the year by observing soil and vegetation in the deepest part of the wetland basin. The least preferred estimate of duration would be based on NWI maps. Water regime within the wetland is based on the number of weeks of flooding and given a Cowardin et al. (1979) classification water regime score (Table 21).

Table 21
Duration of Wetland Flooding with Cowardin et al. (1979) Water Regime

Flooding Condition	Weeks Flooded	Water Regime
Temporarily flooded	1 - 4	A
Seasonally flooded	5 - 17	C
Semipermanently flooded	18 - 40	F
Intermittently exposed	41 - 51	G
Permanently flooded	52	H

Examples of direct hydrologic modification of the wetland include removal of water from the wetland for irrigation or supplementing the water budget by diverting runoff to the wetland. The latter is a common practice around transportation corridors. An example of indirect hydrologic modification is tilling or ditching the wetland to drain it for agriculture. The variable $V_{HYDROMOD}$ is scored by determining the number of weeks of the year the wetland floods under normative water budget conditions and projecting the change in duration in view of past or future projects. If the water regime is normative, then the current subindex score is 1.0. If there is a change in water regime, then the subindex score is determined by the matrix in Table 22, where the normative water regime is sited across the top row of the matrix table and the projected water regime is estimated and sited along the left of the matrix table. The intersection of normative and projected water regimes provides the subindex score.

Table 22
Matrix of Cowardin Water Regime in Which Subindex Scores Are Established by Determining the Normative and Projected Water Regimes

Altered Cowardin Water Regime \ Normative Cowardin Water Regime	A	C	F	G	H
A	1.0	0.7	0.5	0.2	0.1
C	0.7	1.0	0.7	0.5	0.2
F	0.5	0.7	1.0	0.7	0.5
G	0.2	0.5	0.7	1.0	0.7
H	0.1	0.2	0.5	0.7	1.0

Geomorphic Modification (V_{GEOMOD}). This variable represents the anthropogenic modification of the geomorphic properties of the wetland through changes either to increase water storage or drain the wetland. Examples of geomorphic modification commonly practiced are tilling or ditching wetlands to remove water or dredging and excavating wetlands to increase water depth. Wetlands have been drained in the past most often so that the wetland can be cultivated and put into crop production. However, ditching or tilling may also

have been done near home sites to drain the area for lawns or simply to reduce the standing water on the property.

The modification to the wetland is geomorphic in nature but directly affects hydrologic properties. Filling, dredging, tilling, and ditching are all modifications that change the fundamental character of the wetland. This variable is calculated as a function of change on a per-area basis and is linked to wetland zonation and vegetation communities (Table 23).

Table 23
Calculation Matrix of Subindex Scores Based on Unaltered and Altered Geomorphic Conditions by Wetland Zone

Altered Wetland Zones	Unaltered Wetland Zones: Low Prairie	Wet Meadow	Shallow Marsh	Deep Marsh
Low Prairie	1.0	0.1	0.0	0.0
Wet Meadow	0.8	1.0	0.8	0.5
Shallow Marsh	0.2	0.8	1.0	0.8
Deep Marsh	0.0	0.2	0.8	1.0

Functional Capacity Index

The assessment model for calculating the FCI is as follows:

$$FCI = \left[\left(\frac{V_{PDEN} + V_{NPDIV} + V_{NPCOV}}{3}\right) \times \left(\frac{V_{HYDROMOD} + V_{GEOMOD}}{2}\right) \times V_{\alpha DIV}\right]^{1/3} \qquad (18)$$

In the model equation, the function of maintaining a characteristic plant community depends on the following factors: (a) the communities within the wetland having sufficient density to provide a natural level of primary production for carbon input to the wetland for maintenance of other functions (e.g., detritus accumulation, trophic support) as well as structure habitat, (b) a plant diversity that is primarily dominated by native species, (c) not only the diversity of those native plants, but also the preponderance of plant coverage, (d) the overall plant diversity, regardless of native or exotic, comensurate with the standard reference, and (e) hydrologic and geomorphic modification that results in significant change in the vegetation communities.

In the first subpart of the equation the three variables are plant density (V_{PDEN}), native plant diversity (V_{NPDIV}), and percent coverage by native plants (V_{NPCOV}). These variables are weighted equally and averaged. Following are the second and third parts of the equation, which deal with any hydrologic changes that result in change in water regime ($V_{HYDROMOD}$) or basin geomorphology (V_{GEOMOD}) or plant α-diversity across wetland zones ($V_{\alpha DIV}$). Each of these three subparts, containing three variables in the first, two variables in the second, and one in the third, is averaged by taking the geometric mean. The geometric mean was selected because the variables or combinations of variables are capable of diminishing this function to the point where it no longer occurs on the site if that portion of the model achieves a subindex score of zero.

Function 5: Maintain Characteristic Invertebrate Food Webs

Definition

The function of Maintaining Characteristic Invertebrate Food Webs is defined as the capacity of the wetland to maintain a characteristic diversity and abundance of soil and aquatic invertebrates. Invertebrates are subject to considerable variation over the annual climatic cycle, thus leading to inaccuracies in functional assessments if the assessment period occurs at a time of the year when densities or diversity are naturally low. Invertebrates may also be difficult to collect, identify, and enumerate without extensive training. Therefore, within the framework of an HGM Functional Assessment of Intermontane Prairie Potholes, this function is based on the evaluation of habitat vegetation structure, hydrographic regime, and water chemistry rather than direct measures of the invertebrates. Use of an Index of Biological Integrity (IBI) (Karr and Chu 1997) to augment an HGM assessment is encouraged. Freshwater Biocriteria for Intermontane Prairie Potholes using analyses of macroinvertebrates show specific metrics that can be adopted as part of a Biocriteria monitoring plan (Ludden 2000).

Rationale for selecting the function

Intermontane pothole wetlands are important sources of aquatic and terrestrial invertebrates, which (a) process organic matter and are often major contributors to decomposition, (b) play an essential role in nutrient cycling, and (c) provide important conduits of trophic support for higher level consumers through the secondary production of their populations. Aquatic insects are particularly sensitive to diminished water quality; thus healthy populations are indicative of physiochemical conditions that are normative (e.g., nontoxic, appropriate thermal regimes, sufficient duration of flooding). The structure of invertebrate assemblages is sensitive to, and determined by, the conditions and resources available within a habitat. The analysis of this function focuses on the ability of the wetland ecosystem to support and maintain a balanced, adaptive community of invertebrate organisms. This is accomplished through an analysis of critical habitat as well as diversity of habitat structure within the wetland.

Characteristics and processes that influence the function

Invertebrate consumption and processing of organic matter significantly affect the nutrient cycling and energy pathways that occur in pothole wetlands functioning at the reference standard level. Various insects (e.g., beetles, flies) and oligochaetes (e.g., earthworms) play a vital role in the physical turnover of soils within the wetland boundary. Detrital organic matter and living root structures within the soil are ingested and processed by these organisms to aid in the decomposition and mineralization of nutrients. Movement of these organisms through the soil increases aeration and microbial processing rates.

Aquatic invertebrates, particularly insects, crustaceans, and molluscs, are often diverse and abundant in shallow and deep marsh habitats. Hundreds of species commonly occupy a variety of benthic, epiphytic, pelagic, and surface habitats (Merritt and Cummins 1996). Although macroinvertebrates have many characteristics that make them ideal for freshwater biomonitoring programs (Rosenburg and Resh 1993), the ecology of wetland macroinvertebrates is not as well understood as that of macroinvertebrates that live in streams where most of the biomonitoring methodologies have been developed.

Macroinvertebrates may serve as sentinel organisms for early warning of water pollution or losses of continuity of particular habitats (Rosenberg and Resh 1993). Likewise, the presence of particular habitats results in a characteristic fauna. Macroinvertebrates are sensitive to a variety of environmental changes and contaminants. Many species react strongly to toxic metals and organic pollution, acidification, salinization, sedimentation, and habitat fragmentation and disturbance (Hellawell 1986; Adamus and Brandt 1990; Johnson, Weiderholm, and Rosenberg 1993).

Description of model variables

Land Use in the Wetland (V_{WETUSE}). This variable is a function of the various land uses within the wetland. For this Guidebook, this area is categorized as the Wet Meadow, Shallow Marsh, and Deep Marsh wetland zones (Stewart and Kantrud 1972). There is considerable hydrogeomorphic variability among wetlands within this HGM class. Intermittent and temporary wetlands may possess only a Wet Meadow wetland zone to the center of the wetland, whereas semipermanent and permanent wetlands may possess a Wet Meadow, Shallow Marsh, and Deep Marsh. The V_{WETUSE} subindex score is based on the descriptive treatment and corresponding Variable Subindex Score given in Table 24.

Table 24
Current Land Use Treatment in the Wet Meadow, Shallow Marsh, and Deep Marsh Wetland Zones and Corresponding Variable Subindex Score

Land Use Treatment	Score
Current Use	
Heavy grazing by livestock	0.10
Dry year crop production	0.20
Moderate grazing by livestock	0.30
Mowed and hayed, but uncultivated field	0.40
Light grazing by livestock	0.60
Fallow, no cultivation or livestock >2 years, but <10 years	0.80
Managed as undisturbed grassland >10 years, but <20 years	0.95
Managed as undisturbed grassland >20 years	1.00
Projected Use	
Fill with paving	0.00
Fill without paving	0.05
Partial fill	0.10

Land Use in the Wetland Edge ($V_{EDGEUSE}$). This variable is a function of the various land uses along the edge of the wetland. The wetland edge is generally categorized as the Low Prairie wetland zone (Stewart and Kantrud 1972). If the Low Prairie is indistinct, then $V_{EDGEUSE}$ is based on the area above the Wet Meadow wetland zone to a distance of 25 m. The $V_{EDGEUSE}$ subindex score is based on the descriptive treatment and corresponding score in Table 25.

Table 25
Current Land Use Treatment in the Low Prairie Wetland Zone and Corresponding Variable Subindex Score

Land Use Treatment	Score
Current Use	
Heavy grazing by livestock	0.10
Annual crop production	0.10
Moderate grazing by livestock	0.40
Mowed and hayed, but uncultivated field	0.50
Light grazing by livestock	0.65
Conservation easement with planting	0.75
Fallow, no cultivation or livestock >2 years, but <10 years	0.90
Managed as undisturbed grassland >10 years, but <20 years	0.95
Managed as undisturbed grassland >20 years	1.00
Projected Use	
Fill with paving	0.00
Fill without paving	0.05
Partial fill	0.10

Depth of the O and A Soil Horizons (V_{O+A_HORIZ}). This variable represents the weighted mean depth of the O and A soil horizons across each of the vegetation communities in the Low Prairie, Wet Meadow, Shallow Marsh, and Deep Marsh wetland zones. V_{O+A_HORIZ} is quantified by direct measurement of the O and A soil horizon depths from soil pits or from soil cores.

The Variable Subindex Score for V_{O+A_HORIZ} is based on the relationship between the added depth of the O horizon and the A horizon and the Variable Subindex Score illustrated in Figure 19.

Plant Density (V_{PDEN}). This variable represents the weighted mean density in stems/m^2 of plants within each of the vegetation communities in the Low Prairie, Wet Meadow, Shallow Marsh, and Deep Marsh. The vegetation in glacial pothole wetlands often appears as concentric rings around the wetland. These rings of vegetation generally coincide with hydrologic variation and have been described extensively in the literature, particularly regarding the Prairie Pothole Region (sensu Stewart and Kantrud 1972; Mitsch and Gosselink 1993).

The weighted mean plant density is determined by a series of vegetation plots taken within each vegetation community. The mean plant density from each vegetation community is multipled by the percent area of the whole wetland occupied by that community. The proportional plant densities of each vegetation community are added to obtain the Weighted Plant Density across the entire wetland.

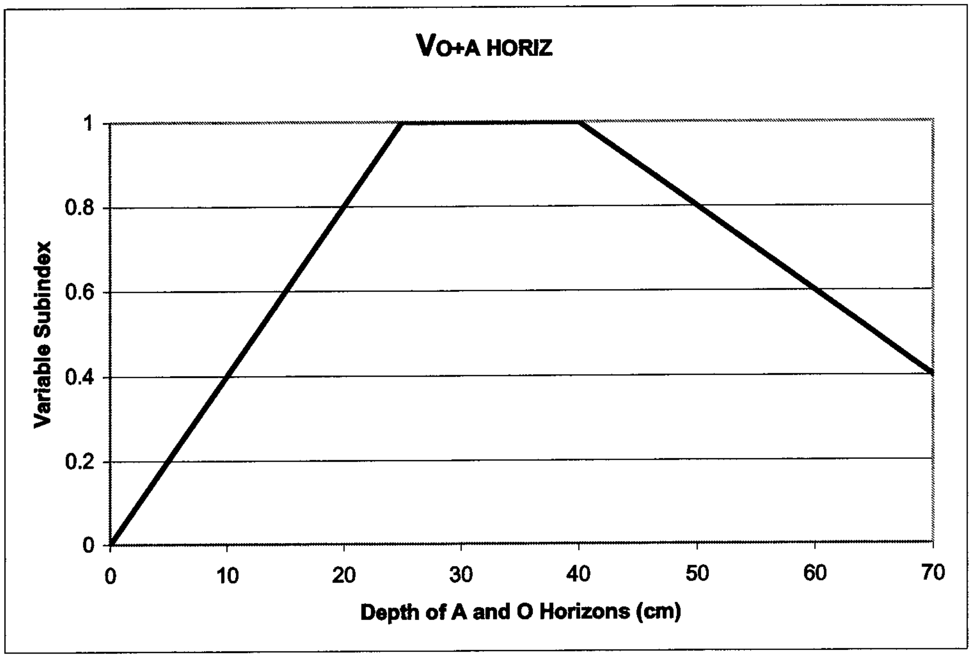

Figure 19. Relationship between O + A Horizon soil depths and the Variable Subindex Scores

The Variable Subindex Score for V_{PDEN}, illustrated in Figure 20, is based on the relationship between the Weighted Plant Density and the algorithm:

$$\text{Variable Subindex} = 0.1946 \ln (\boldsymbol{WPD}) - 0.7548 \qquad (19)$$

Sediment Delivery (V_{SED}). This variable represents the potential amount of sediment entering a pothole wetland as a product of erosion from adjacent uplands. This is based on the RUSLE:

$$RUSLE\_Index = R \times K \times L \times S \times C \times P \qquad (20)$$

where

R = rainfall-runoff erosivity factor, which for this Reference Domain is 1.0

K = soil erodibility factor of the adjacent upland based on Table 26

L = mean slope length, feet, of four transects from the catchment boundary to the outer edge of the Low Prairie wetland zone

S = mean slope, percent, of the four transects = $h/l \times 100$

C = cover management factor

P = support practices factor

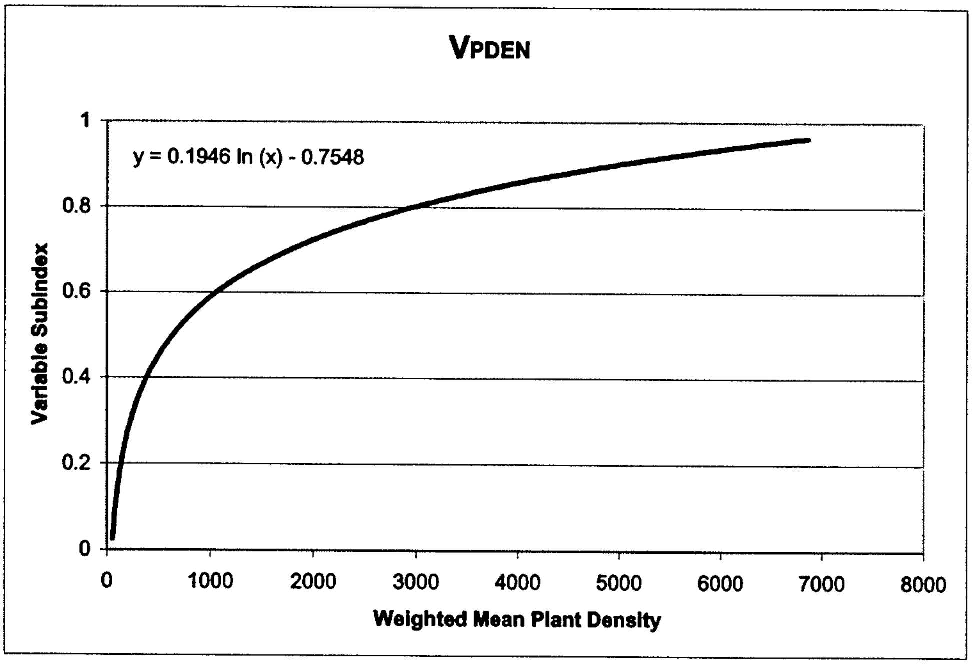

Figure 20. Correlation between Weighted Plant Density and the Variable Subindex Score

Table 26
Soil Texture, Geometric Mean Particle Size, and Corresponding K Erodibility Factor

Soil Texture	Log Mean Geometric Particle Diameter	K Erodibility Factor
Silty clay	-1.2	0.041
Silt	-1.0	0.034
Silty clay loam	-0.9	0.03
Clay	-0.7	0.02
Silt loam	-0.6	0.018
Clay loam	-0.5	0.014
Loam	-0.4	0.01
Sandy clay	-0.3	0.009
Sandy clay loam	-0.2	0.007
Sandy loam	-0.2	0.006
Loamy sand	-0.1	0.003
Sand	0.0	0.001

In this procedure *CP* is calculated as a single factor where

$$CP = \frac{1}{\sqrt{\left[\frac{(V_{UPUSE} + V_{EDGEUSE})}{2}\right] \times V_{WETUSE}}} \tag{21}$$

The Variable Subindex Score for V_{SED} is based on the relationship between the RUSLE and the Variable Subindex Score described by the equation:

$$V_{SED} \text{ Variable Subindex} = -0.1561 \times \ln(RUSLE) + 0.5243 \tag{22}$$

and illustrated in Figure 21.

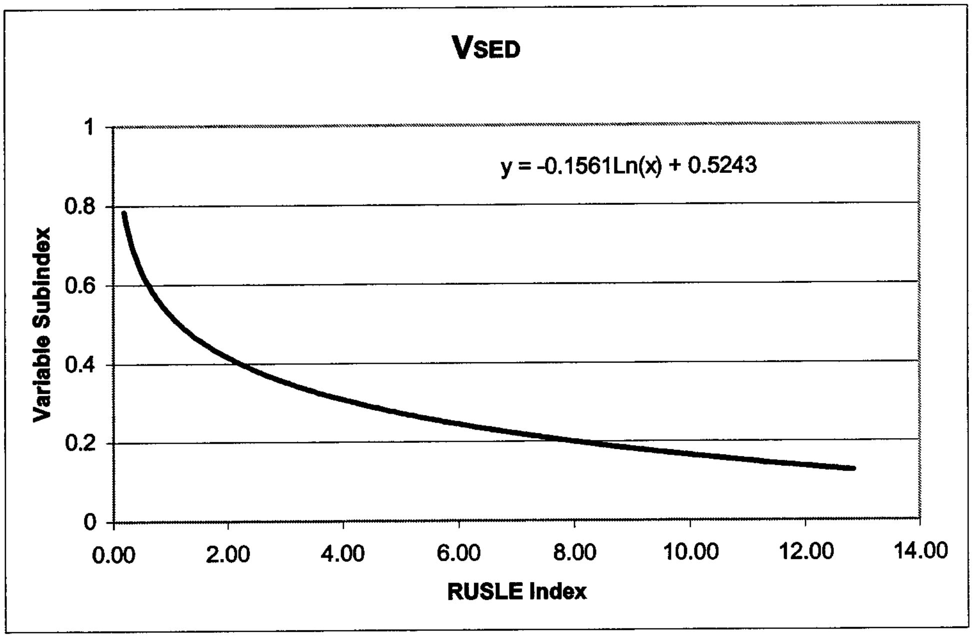

Figure 21. Relationship between RUSLE Index and the Variable Subindex Score

Hydrologic Modification ($V_{HYDROMOD}$). This variable represents the change in duration of flooding within the wetland expressed as the number of weeks in the year that ponded water is present. This variable is based on the duration of flooding (i.e., water regime) in a typical water year, since water storage can be significantly less following long-term drought or greatly extended following a long wet period. If possible, this variable should be evaluated directly by observation at the wetland site. If this is not possible, then indicators may be used to estimate the number of weeks of inundation during the year by observing soil and vegetation in the deepest part of the wetland basin. The least preferred estimate of duration would be based on NWI maps. Water regime within the wetland is based on the number of weeks of flooding and given a Cowardin et al. (1979) classification water regime score (Table 27).

Examples of direct hydrologic modification of the wetland include removal of water from the wetland for irrigation or supplementing the water budget by diverting runoff to the wetland. The latter is a common practice around transportation corridors. An example of indirect hydrologic modification is tilling or ditching the wetland to drain it for agriculture. The variable $V_{HYDROMOD}$ is scored

Table 27
Duration of Wetland Flooding with Cowardin et al. (1979) Water Regime

Flooding Condition	Weeks Flooded	Water Regime
Temporarily flooded	1 - 4	A
Seasonally flooded	5 - 17	C
Semipermanently flooded	18 - 40	F
Intermittently exposed	41 - 51	G
Permanently flooded	52	H

by determining the number of weeks of the year the wetland floods under normative water budget conditions and projecting the change in duration in view of past or future projects. If the water regime is normative, then the current subindex score is 1.0. If there is a change in water regime, then the subindex score is determined by the matrix in Table 28, where the normative water regime is sited across the top row of the matrix table and the projected water regime is estimated and sited along the left of the matrix table. The intersection of normative and projected water regimes provides the subindex score.

Table 28
Matrix of Cowardin Water Regime in Which Subindex Scores Are Established by Determining the Normative and Projected Water Regimes

Normative Cowardin Water Regime

Altered Cowardin Water Regime	A	C	F	G	H
A	1.0	0.7	0.5	0.2	0.1
C	0.7	1.0	0.7	0.5	0.2
F	0.5	0.7	1.0	0.7	0.5
G	0.2	0.5	0.7	1.0	0.7
H	0.1	0.2	0.5	0.7	1.0

Geomorphic Modification (V_{GEOMOD}). This variable represents the anthropogenic modification of the geomorphic properties of the wetland through changes either to increase water storage or drain the wetland. Examples of geomorphic modification commonly practiced are tilling or ditching wetlands to remove water or dredging and excavating wetlands to increase water depth. Wetlands have been drained most often in the past so that the wetland can be cultivated and put into crop production. However, ditching or tilling may also have been done near home sites to drain the area for lawns or simply to reduce the standing water on the property.

The modification to the wetland is geomorphic in nature, but directly affects hydrologic properties. Filling, dredging, tilling, and ditching are all modifications that change the fundamental character of the wetland. This variable is calculated as a function of change on a per-area basis and is linked to wetland zonation and vegetation communities (Table 29).

Table 29
Calculation Matrix of Subindex Scores Based on Unaltered and Altered Geomorphic Conditions by Wetland Zone

Altered Wetland Zones	Unaltered Wetland Zones: Low Prairie	Wet Meadow	Shallow Marsh	Deep Marsh
Low Prairie	1.0	0.1	0.0	0.0
Wet Meadow	0.8	1.0	0.8	0.5
Shallow Marsh	0.2	0.8	1.0	0.8
Deep Marsh	0.0	0.2	0.8	1.0

Functional Capacity Index

The assessment model for calculating the FCI is as follows:

$$FCI = \left\{ \left(\frac{V_{WETUSE} + V_{EDGEUSE}}{2} \right) \times \left[\frac{\left(V_{O+A\_HORIZ} + V_{PDEN} + V_{SED} \right)}{3} \right] \times V_{HYDROMOD} \times V_{GEOMOD} \right\}^{1/4} \quad (23)$$

In the model equation, the function of maintaining characteristic invertebrate habitat depends on the following factors: (a) land use in and immediately around the wetland, (b) plant density, soil characteristics, and sedimentation, (c) the modification of wetland water regime, and (d) the modification of wetland zonation.

There are four subparts to the algorithm that describes this function; each subpart is weighted equally by taking the geometric mean. In the first part of the equation, the potential quality and level of disturbance of the invertebrate habitat are described by the variables V_{WETUSE} and $V_{EDGEUSE}$. The second subpart of the equation comprises the three variables V_{O+A_HORIZ}, V_{PDEN}, and V_{SED}. These variables describe the plant and soil characteristics and the rate of sedimentation to and within the wetland. The third subpart comprises the single variable $V_{HYDROMOD}$, which describes any hydrologic changes in the wetland as a whole. The fourth subpart of the model is described by the single variable V_{GEOMOD}, which describes the modification in the distribution of zonation. Subparts 3 and 4 are given equal weight with the land use variables and the plant and soil variables because of the strong influence of these factors on the viability of the wetland to perform this function. For example, if flooding has been altered such that the wetland ceases to be a wetland, then characteristic invertebrate fauna no longer have the habitat to complete life cycles.

Function 6: Maintain Characteristic Vertebrate Habitats

Definition

The function of Maintaining Characteristic Vertebrate Habitats is defined as the capacity of the wetland to maintain the habitats/resources necessary for a characteristic diversity and abundance of herptiles (i.e., amphibians and reptiles), birds, and mammals. Many of the representatives of these vertebrate groups are extremely mobile with high variability in spatial and/or temporal use of pothole wetlands. Migratory waterfowl and neotropical birds are excellent examples of the temporal nature of the use of pothole wetlands by various bird species. Some waterfowl species may use a particular pothole as a resting site during migration (e.g., snow geese, pintails), while others may use Northern Rocky Mountain Intermontane Potholes for nesting (e.g., mallards, teal), and thus use a particular pothole for several months. In contrast, frogs and turtles are far less mobile than birds and generally will remain near the pothole of their origin for several years

with migrations generally limited to less than 1-2 km. Likewise, very small mammals (e.g., voles, shrews) have correspondingly small home ranges, while large mammals that commonly use intermontane pothole wetlands (e.g., elk, deer) may range over several kilometers in a single day. The consequence of high spatial and temporal variability among mammals is that direct measurement of the presence or absence of species within the time frame of the protocols of a rapid assessment is often impractical or misleading. Therefore, functional assessment protocols for this function are based on indicators of high-quality, diverse habitats for the many vertebrate species. Potential independent, quantitative measures for validating the functional index include detailed, species- or guild-specific surveys and wildlife sampling techniques.

Rationale for selecting the function

Wetlands are attractive to vertebrates because of their abundant nutrient resources and habitat diversity (Weller 1988). Intermontane pothole wetlands are used extensively by many species of vertebrates from frogs and toads to ungulates and bears. Vertebrates function as primary consumers (e.g., grazers, browsers, seed eaters) and secondary consumers (carnivores). Likewise, some species are trophic generalists while others are highly specialized. The diversity of vertebrates within pothole-dominated landscapes appears to be closely associated with the diversity of habitat created by geomorphic, hydrologic, and vegetative diversity in structure and regimes. Thus, performance of this function is founded on the ecological interconnectivity between habitat complexity and support of the characteristic vertebrate fauna that typifies pothole wetlands in the northern Rocky Mountains. Habitat requirements are highly variable within and between species. An example of within-species variation in requirements is that among ducks, in which nesting habitat may be different from brood-rearing habitat. Between-species variation in habitat requirements may be illustrated by the extreme difference in cover requirements between ungulates and voles.

The maintenance of a diverse vertebrate fauna is dependent on a diverse and productive habitat. Thus, the rationale of this function is based on the connectivity between a diverse and characteristic vertebrate fauna that within the constraints of a rapid assessment focuses on the characteristics of habitat features and their distribution across spatial scales.

Characteristics and processes that influence the function

Many factors affect the quality and quantity of vertebrate habitat among intermontane prairie pothole wetlands. The fundamental drivers of wetland structure and function (i.e., hydrology and geomorphology) greatly affect vertebrate response. For example, not only will a temporarily flooded pothole wetland that holds water for only a few weeks possess significantly different vegetation from that of a semipermanent or permanently flooded wetland, but its support of necessary aquatic habitat for amphibian immature life stages will also be significantly different. Thus, duration of flooding is an important variable that directly influences the characteristics and processes of this function. Likewise,

the ratio of water surface area to volume in a pothole, particularly as influenced by the depth and duration of flooding, has a significant effect on vertebrate habitat. For example, turtles require permanent water depth of a meter or more for sustained presence in a glacial pothole wetland. Depth of the water also has an influence on the presence of diving or dabbling ducks. Alterations of hydrographic regimes or geomorphic configuration affect the primary response variables expressed by the vegetation. The drainage of wetlands for agriculture, highway construction, or other human uses has been a significant factor in wetland degradation (Mitsch and Gosselink 1993). Land use within the drainage basin of a pothole, including cultivation, grazing by cattle, or haying, affects vertebrate habitat. Proximity to primary or secondary highways and roads has a deleterious effect on wildlife. Studies have shown that turtles residing in potholes that border a highway have a significant mortality rate associated with migration from one pothole to another as they cross motor traffic. Alterations of vegetation affect trophic structure and nutrient and energy flux that are integral to the trophic support of vertebrates. For example, grazing (particularly over-grazing) reduces vegetation, which displaces native herbivores. Cattle grazing may have other long-term effects as well, including change in the composition of vegetation (e.g., increase in nonnative introduction) or direct physical disturbances (e.g., damage to ground-nesting birds, change in microtopography, "pugging" of soils).

The food web of freshwater marsh wetlands is dependent on the accumulation of vegetation and the microbial processing associated with detrital decomposition (Gallager 1978). The direct consumption of macrophytes by geese, muskrats, and other herbivores is very prevalent in many depressional wetlands. Although mammal production has consumed relatively small amounts of the primary production in wetlands (Pelikan 1978), in contrast, the authors have observed in a few isolated cases the removal of virtually all emergent vegetation under heavy grazing pressure from cattle. In conjunction with hydrologic factors, species composition, density, and variation of vegetation are the primary variables controlling vertebrate habitat.

Description of model variables

Upland Land Use (V_{UPUSE}). This variable is a function of the various land uses in the upland above the Low Prairie wetland zone. If the catchment boundary is extremely large or indistinct, then a perimeter of 100 m from the upper boundary of the Low Prairie is used as the functional upland zone of influence. The variable is scored based on the descriptive treatment and corresponding score in Table 30.

Land Use in the Wetland Edge ($V_{EDGEUSE}$). This variable is a function of the various land uses along the edge of the wetland. The wetland edge is generally categorized as the Low Prairie wetland zone (Stewart and Kantrud 1972). If the Low Prairie is indistinct, then $V_{EDGEUSE}$ is based on the area above the Wet Meadow wetland zone to a distance of 25 m. The variable $V_{EDGEUSE}$ is scored based on the descriptive treatment and corresponding score in Table 31.

Table 30
Current Land Use Treatment in the Upland and Corresponding Variable Subindex Score

Current Land Use Treatment	Score
Commercial right-of-way or paved driveway	0.00
Private right-of-way or unpaved driveway	0.10
Heavy grazing by livestock	0.20
Annual crop production	0.20
Generalized soil disturbance	0.30
Residential or commercial lawn	0.40
Moderate grazing by livestock	0.50
Mowed and hayed, but uncultivated field	0.60
Light grazing by livestock	0.70
Conservation easement with planting	0.85
Fallow, no cultivation or livestock >2 years, but <10 years	0.90
Managed as undisturbed grassland >10 years, but < 20 years	0.95
Managed as undisturbed grassland > 20years	1.00

Table 31
Current Land Use Treatment in the Low Prairie Wetland Zone and Corresponding Variable Subindex Score

Land Use Treatment	Score
Current Use	
Heavy grazing by livestock	0.10
Annual crop production	0.10
Moderate grazing by livestock	0.40
Mowed and hayed, but uncultivated field	0.50
Light grazing by livestock	0.65
Conservation easement with planting	0.75
Fallow, no cultivation or livestock >2 years, but <10 years	0.90
Managed as undisturbed grassland >10 years, but <20 years	0.95
Managed as undisturbed grassland >20 years	1.00
Projected Use	
Fill with paving	0.00
Fill without paving	0.05
Partial fill	0.10

Land Use in the Wetland (V_{WETUSE}). This variable is a function of the various land uses within the wetland. For this Guidebook, this area is categorized as the Wet Meadow, Shallow Marsh, and Deep Marsh wetland zones (Stewart and Kantrud 1972). There is considerable hydrogeomorphic variability among wetlands within this HGM class. Intermittent and temporary wetlands may possess only a Wet Meadow wetland zone to the center of the wetland, whereas semipermanent and permanent wetlands may possess a Wet Meadow, Shallow Marsh, and a Deep Marsh. The variable V_{WETUSE} is scored based on the descriptive treatment and corresponding Variable Subindex Score in Table 32.

Table 32
Current Land Use Treatment in the Wet Meadow, Shallow Marsh, and Deep Marsh Wetland Zones and Corresponding Variable Subindex Score

Land Use Treatment	Score
Current Use	
Heavy grazing by livestock	0.10
Dry year crop production	0.20
Moderate grazing by livestock	0.30
Mowed and hayed, but uncultivated field	0.40
Light grazing by livestock	0.60
Fallow, no cultivation or livestock >2 years, but <10 years	0.80
Managed as undisturbed grassland >10 years, but <20 years	0.95
Managed as undisturbed grassland >20 years	1.00
Projected Use	
Fill with paving	0.00
Fill without paving	0.05
Partial fill	0.10

Plant Density (V_{PDEN}). This variable represents the weighted mean density in stems/m^2 of plants within each of the vegetation communities in the Low Prairie, Wet Meadow, Shallow Marsh, and Deep Marsh. The vegetation in glacial pothole wetlands often appears as concentric rings around the wetland. These rings of vegetation generally coincide with hydrologic variation and have been described extensively in the literature, particularly regarding the Prairie Pothole Region (sensu Stewart and Kantrud 1972; Mitsch and Gosselink 1993).

The weighted mean plant density is determined by a series of vegetation plots taken within each vegetation community. The mean plant density from each vegetation community is multipled by the percent area of the whole wetland occupied by that community. The proportional plant densities of each vegetation community are added to obtain the Weighted Plant Density across the entire wetland.

The Variable Subindex Score for V_{PDEN} is based on the relationship between the Weighted Plant Density and the algorithm:

$$\text{Variable Subindex} = 0.1946 \ln (\boldsymbol{WPD}) - 0.7548 \tag{24}$$

illustrated in Figure 22.

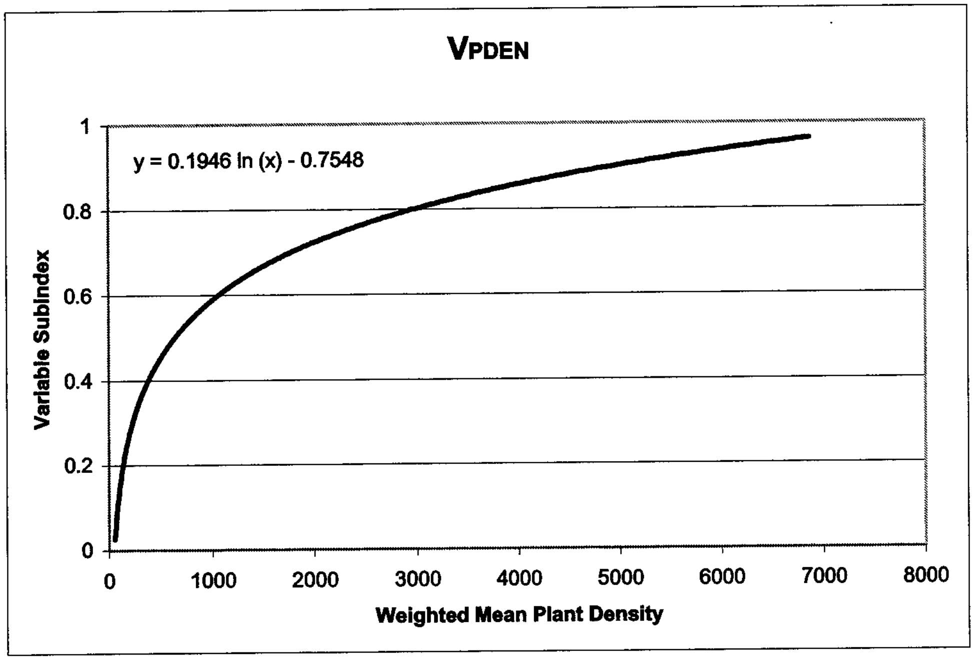

Figure 22. Correlation between Weighted Plant Density and the Variable Subindex Score

Percent Native Plant Diversity (V_{NPDIV}). This variable represents the percent diversity of native plants within the wetland (i.e., below the Upland/Low Prairie boundary). Native plant diversity is important to maintaining ecosystem structure and function. Rates of processes (e.g., elemental cycling, detritus accumulation), depend on native plants as well as animal populations, which are adapted to native plants for food, cover, or nesting. Nonnative plants alter the natural physical structure that is characteristic of a native community and are often indicators of unnatural levels of disturbance. For example, canary grass (*Phalaris arundinacea*) is a nonnative that commonly occurs in the Wet Meadow habitat type of the Intermontane Glacial Potholes where an unnaturally high rate of sedimentation has been entering the wetland from upland land use, such as cultivation.

This variable is a comparison of the native to nonnative species complex. It requires obtaining a complete species list including a determination of native and nonnative status. V_{NPDIV} is measured as the weighted average percent native species (NS) across all vegetation communities in the Low Prairie, Wet Meadow, Shallow Marsh, and Deep Marsh. This value is then scaled to give the Variable

Subindex Score based on the following regression equation and illustrated in Figure 23.

$$\text{Variable Subindex } = 0.0092\,(\%NS) + 0.0768 \qquad (25)$$

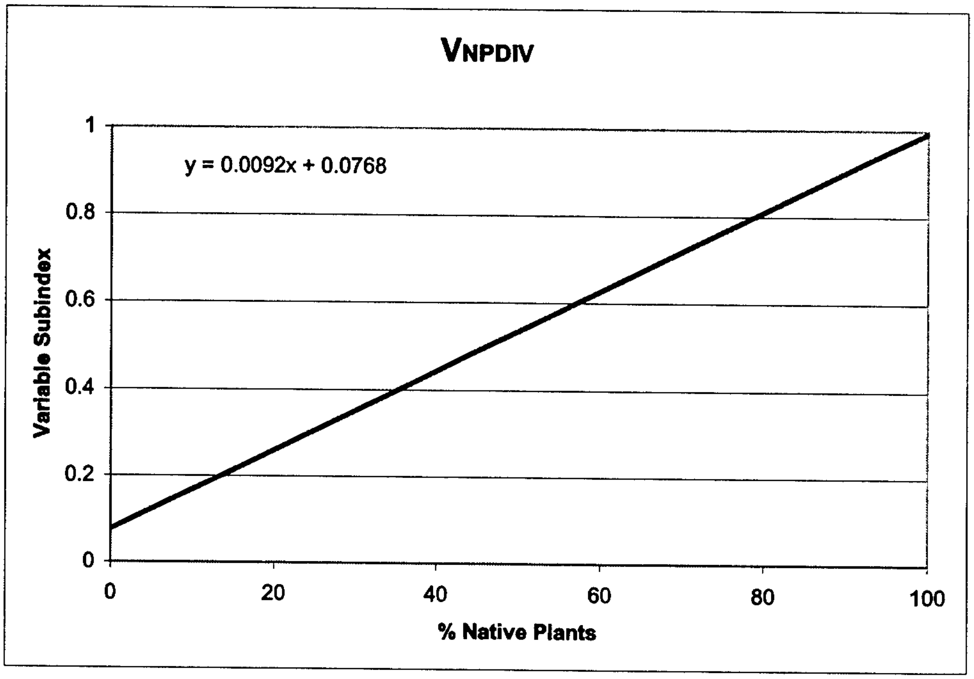

Figure 23. Correlation between Percent Native Plants and the Variable Subindex Score

Percent Coverage by Native Plants (V_{NPCOV}). This variable represents the weighted mean percent coverage of native plants within each of the vegetation communities of the wetland. Similar in concept and calculation to the variable V_{PDEN}, (V_{NPCOV}) is a measure of the percent coverage by native plants across the wetland. This variable is quantified by estimating the percent coverage within each community that is contributed by native plants.

Native plant coverage is important to maintaining ecosystem structure and function. Rates of processes (e.g., elemental cycling, detritus accumulation) depend on native plants, as well as animal populations, which are adapted to native plants, for food, cover, or nesting. Nonnative plants alter the natural physical structure that is characteristic of a native community and are often indicators of unnatural levels of disturbance.

The correlation between percent native plant coverage and the variable subindex among the reference wetlands is described by the following regression equation and illustrated in Figure 24.

$$\text{Variable Subindex} = y = 0.0076\ (\boldsymbol{WNPC}) + 0.2166 \quad (26)$$

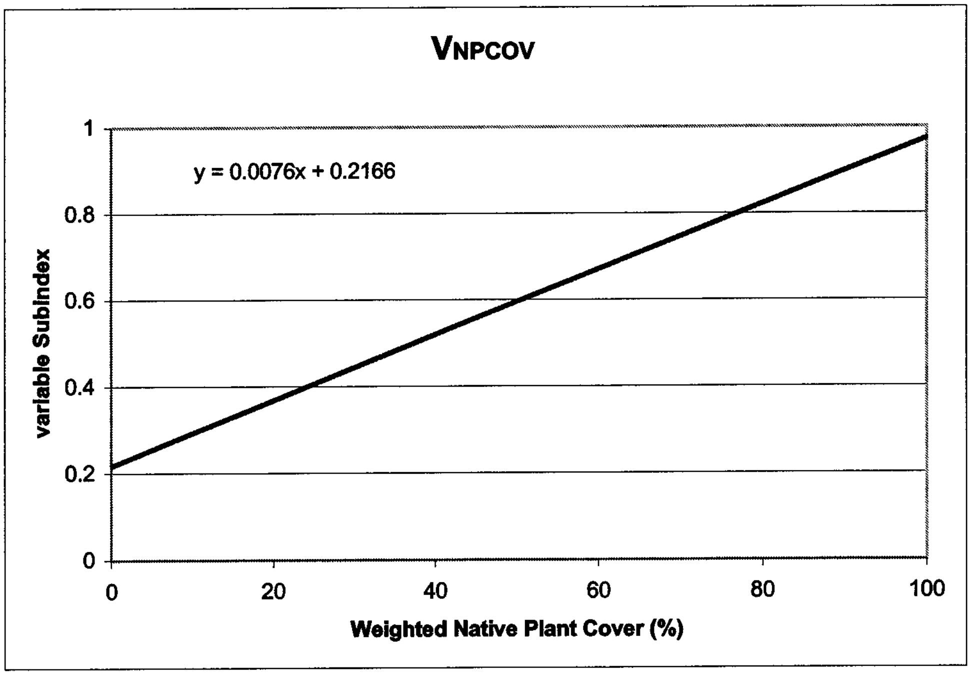

Figure 24. Correlation between Percent Native Plant Cover and the Variable Subindex Score

Plant α-diversity across Wetland Zones ($V_{\alpha DIV}$). This variable is a measure of the α-diversity of plant species across each vegetation community and wetland zone. Reference standard wetlands in the Intermontane Glacial Pothole reference domain have numerous species distributed across multiple habitat types. Typically, the Low Prairie has the greatest species diversity, followed by the Wet Meadow and then the Shallow and Deep Marshes. For analyses on these pothole wetlands, this variable is measured as the weighted average Variable Subindex Score, where the Low Prairie, Wet Meadow, and the two Marsh types of wetland zones have independent regression relationships.

The correlation between α-diversity and the variable subindex for the three wetland zones and across the reference wetlands is described by the following three regression equations and as illustrated in Figure 25.

$$\text{Low Prairie Subindex} = 0.2431 \times \ln(\alpha\text{-diversity}) + 0.6483 \quad (27)$$

$$\text{Wet Meadow Subindex} = 0.2087 \times \ln(\alpha\text{-diversity}) + 0.5943 \quad (28)$$

$$\text{Shallow and Deep Marsh} = 0.203 \times \ln(\alpha\text{-diversity}) + 0.4984 \quad (29)$$

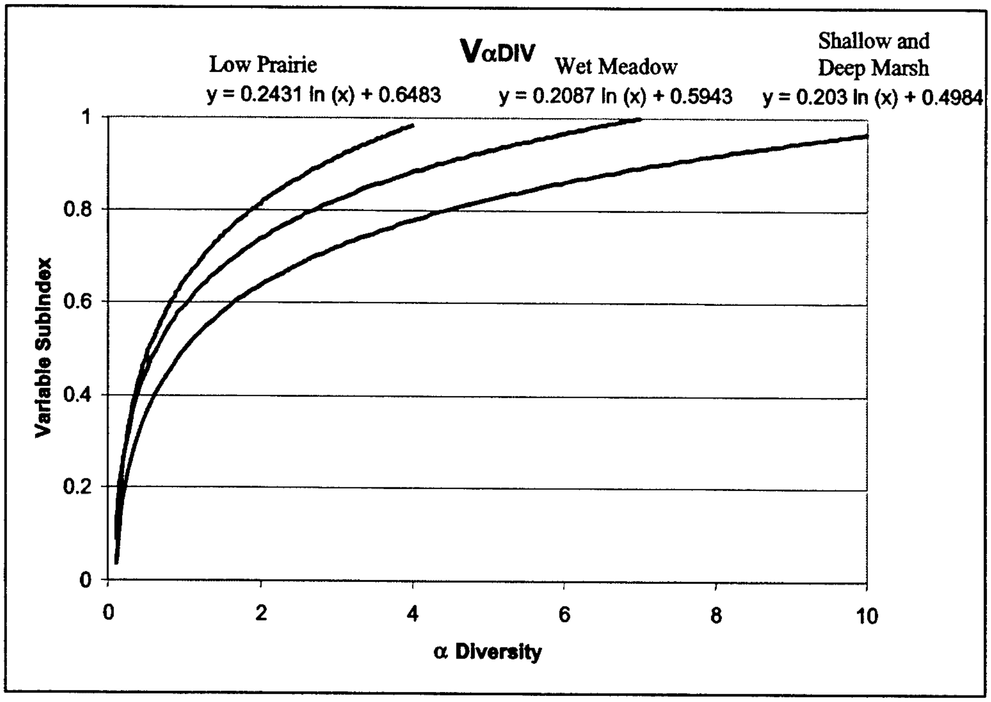

Figure 25. Correlation between α-diversity and the Variable Subindex Score

Hydrologic Modification ($V_{HYDROMOD}$). This variable represents the change in duration of flooding within the wetland expressed as the number of weeks in the year that ponded water is present. This variable is based on the duration of flooding (i.e., water regime) in a typical water year since water storage can be significantly less following long-term drought or greatly extended following a long wet period. If possible, this variable should be evaluated directly by observation at the wetland site. If this is not possible, then indicators may be used to estimate the number of weeks of inundation during the year by observing soil and vegetation in the deepest part of the wetland basin. The least preferred estimate of duration would be based on NWI maps. Water regime within the wetland is based on the number of weeks of flooding and given a Cowardin et al. (1979) classification water regime score (Table 33).

Table 33
Duration of Wetland Flooding with Cowardin et al. (1979) Water Regime

Flooding Condition	Weeks Flooded	Water Regime
Temporarily flooded	1 - 4	A
Seasonally flooded	5 - 17	C
Semipermanently flooded	18 - 40	F
Intermittently exposed	41 - 51	G
Permanently flooded	52	H

Examples of direct hydrologic modification of the wetland include removal of water from the wetland for irrigation or supplementing the water budget by diverting runoff to the wetland. The latter is a common practice around transportation corridors. An example of indirect hydrologic modification is tilling or ditching the wetland to drain it for agriculture. The variable $V_{HYDROMOD}$ is scored by determining the number of weeks of the year the wetland floods under normative water budget conditions and projecting the change in duration in view of past or future projects. If the water regime is normative, then the current subindex score is 1.0. If there is a change in water regime, then the subindex score is determined by the matrix in Table 34, where the normative water regime is sited across the top row of the matrix table and the projected water regime is estimated and sited along the left of the matrix table. The intersection of normative and projected water regimes provides the subindex score.

Table 34
Matrix of Cowardin Water Regime in Which Subindex Scores Are Established by Determining the Normative and Projected Water Regimes

Altered Cowardin Water Regime	Normative Cowardin Water Regime: A	C	F	G	H
A	1.0	0.7	0.5	0.2	0.1
C	0.7	1.0	0.7	0.5	0.2
F	0.5	0.7	1.0	0.7	0.5
G	0.2	0.5	0.7	1.0	0.7
H	0.1	0.2	0.5	0.7	1.0

Geomorphic Modification (V_{GEOMOD}). This variable represents the anthropogenic modification of the geomorphic properties of the wetland through modifications that have the purpose of either increasing water storage or draining the wetland. Examples of geomorphic modification commonly practiced are tilling

or ditching wetlands to remove water or dredging and excavating wetlands to increase water depth. Wetlands have been drained in the past most often so that the wetland can be cultivated and put into crop production. However, ditching or tilling may also have been done near home sites to drain the area for lawns or simply to reduce the standing water on the property.

The modification to the wetland is geomorphic in nature but directly affects hydrologic properties. Filling, dredging, tilling, and ditching are all modifications that change the fundamental character of the wetland. This variable is calculated as a function of change on a per-area basis and is linked to wetland zonation and vegetation communities (Table 35).

Table 35
Calculation Matrix of Subindex Scores Based on Unaltered and Altered Geomorphic Conditions by Wetland Zones

Altered Wetland Zones	Unaltered Wetland Zones: Low Prairie	Wet Meadow	Shallow Marsh	Deep Marsh
Low Prairie	1.0	0.1	0.0	0.0
Wet Meadow	0.8	1.0	0.8	0.5
Shallow Marsh	0.2	0.8	1.0	0.8
Deep Marsh	0.0	0.2	0.8	1.0

Functional Capacity Index

The assessment model for calculating the functional capacity index is as follows:

$$FCI = \left[\left(\frac{V_{UPUSE} + V_{EDGEUSE} + V_{WETUSE}}{3} \right) \times \left(\frac{V_{PDEN} + V_{NPDIV} + V_{NPCOV} + V_{\alpha DIV}}{4} \right) \times V_{HYDROMOD} \times V_{GEOMOD} \right]^{\frac{1}{4}} \tag{30}$$

In the model equation, the function of maintaining characteristic vertebrate habitat depends on the following factors: (a) land use in and immediately around the wetland, (b) plant diversity, coverage, and soil characteristics, (c) modifications to the hydrologic regime, and (d) modifications to the geomorphic character of the wetland.

There are four subparts to the algorithm that describes this function. These four subparts are weighted equally by taking their geometric mean, thus if any one of these achieves a score of 0, the function no longer is occurring in the wetland. In the first part of the equation, the potential quality and level of disturbance of the vertebrate habitat are described by the land use variables within and around the wetland: V_{UPUSE}, V_{WETUSE}, and $V_{EDGEUSE}$. The second subpart of the equation is composed of the four vegetation variables V_{PDEN}, V_{NPDIV}, V_{NPCOV}, and $V_{\alpha DIV}$. These variables describe the plant characteristics within the wetland. The third and fourth subparts are composed of the variables describing any modifications to the hydrologic regime ($V_{HYDROMOD}$) and any geomorphic modification of wetland zonation (V_{GEOMOD}).

Function 7: Maintain Wetland Interspersion and Connectivity

Definition

The function of Maintaining Wetland Interspersion and Connectivity is a landscape feature that maintains the habitat interconnectivity and proximity necessary for a characteristic plant and animal diversity and abundance (i.e., largely beta and gamma diversity). There is no longer any question about the fact that cumulative impacts have important effects on wetland organisms (Harris 1988). There is growing concern over the loss of biodiversity that is central not only to the maintenance of the physical, chemical, and biological integrity of the nation's freshwaters as embodied in the Federal Clean Water Act, but is also central to the Federal Endangered Species Act. This function focuses on two important components of maintaining interspersion and habitat connectivity: land use and wetland proximity and density. These include local, intermediate, and regional connections and hydrologic groundwater dependencies to maintain storage and/or diversity of wetlands. There is growing evidence that habitat fragmentation is detrimental to many species, underscoring the importance of making management decisions regarding entire landscapes.

Rationale for selecting the function

Wildlife ecologists have generally assumed that most important ecological processes that affect populations and communities operate at localized spatial

scales. However, there has been increased recognition over the past decade that habitat variation has a profound influence on wildlife and operates at multiple spatial scales. The decline of many species has been linked directly to habitat loss and fragmentation. To capture this concept, the role of wetland function within a landscape context has been included.

Structural connectivity varies along a continuum and is the inverse of the proportion of linkages that must be added to have a connected system (Forman and Godron 1986) in which the fewer the gaps in habitat continuity, the higher the population connectivity. Functional or behavioral connectivity refers to how connected an area is for a process, such as an animal moving through different types of landscape elements (i.e., interspersion). Thus, this function is quantified and scaled after land use patterns that affect flows and movements across the landscape or between wetlands. Potential independent, quantitative measures for validating the functional index include patch-centered measures (e.g., isolation of patch, accessibility of patch, dispersion of patches, and nearest neighbor probabilities) (Forman and Godron 1986).

Characteristics and processes that influence the function

This function is largely founded on the premise that the patterning of landscape elements (i.e., glacial pothole wetlands) strongly influences ecological relationships between various wildlife populations. This discussion focuses in this function on the relative role of land use in and around the wetland and on two wetland/landscape features; the density of wetlands in the landscape and the proximity of the assessment wetland to its nearest neighbors. Also, increased disturbance corridors lead to increases in introductions of exotics. Most vertebrates require not only food resources to sustain population, but also structural habitat and cover associated with predator avoidance, nesting, and resting. Populations also require exchange of genetic material between metapopulations to maintain long-term viability. To maintain these vital associations, vertebrate populations that are associated with glacial pothole wetlands need to be able to move between neighboring wetlands. Thus, various landscape features have a significant effect on the connectivity and interspersion of these landscape patches. For example, an upland that is a cultivated field or pasture that has been intensively grazed will lack the habitat structure necessary for terrestrial vertebrates to move freely between adjacent wetlands. Likewise, birds may lack the cover necessary to raise broods or move easily between wetlands with their young. Ditching/draining alters groundwater flow paths, which can also affect habitat structural connections/corridors. A ditch can narrow a broad wet meadow connection. Draining one wetland will reduce groundwater flow to down-gradient discharge sites/wetlands, making them smaller, more ephemeral, and more isolated and producing a more fragmented landscape.

Description of model variables

Upland Land Use (V_{UPUSE}). This variable is a function of the various land uses in the upland above the Low Prairie wetland zone. If the catchment

Table 36
Current Land Use Treatment in the Upland and Corresponding Variable Subindiex Score

Current Land Use Treatment	Score
Commercial right-of-way or paved driveway	0.00
Private right-of-way or unpaved driveway	0.10
Heavy grazing by livestock	0.20
Annual crop production	0.20
Generalized soil disturbance	0.30
Residential or commercial lawn	0.40
Moderate grazing by livestock	0.50
Mowed and hayed, but uncultivated field	0.60
Light grazing by livestock	0.70
Conservation easement with planting	0.85
Fallow, no cultivation or livestock >2 years, but <10 years	0.90
Managed as undisturbed grassland >10 years, but < 20 years	0.95
Managed as undisturbed grassland > 20 years	1.00

boundary is extremely large or indistinct, then a perimeter of 100 m from the upper boundary of the Low Prairie is used as the functional upland zone of influence. The variable is scored based on the descriptive treatment and corresponding score in Table 36.

Land Use in the Wetland Edge ($V_{EDGEUSE}$). This variable is a function of the various land uses along the edge of the wetland. The wetland edge is generally categorized as the Low Prairie wetland zone (Stewart and Kantrud 1972). If the Low Prairie is indistinct, then $V_{EDGEUSE}$ is based on the area above the Wet Meadow wetland zone to a distance of 25 m. The variable $V_{EDGEUSE}$ is scored based on the descriptive treatment and corresponding score in Table 37.

Land Use in the Wetland (V_{WETUSE}). This variable is a function of the various land uses within the wetland. For this Guidebook, this area is categorized as the Wet Meadow, Shallow Marsh, and Deep Marsh wetland zones (Stewart and Kantrud 1972). There is considerable hydrogeomorphic variability among wetlands within this HGM class. Intermittent and temporary wetlands may possess only a Wet Meadow wetland zone to the center of the wetland, whereas semipermanent and permanent wetlands may possess a Wet Meadow, Shallow Marsh, and Deep Marsh. The variable V_{WETUSE} is scored based on the descriptive treatment and corresponding Variable Subindex Score in Table 38.

Table 37
Current Land Use Treatment in the Low Prairie Wetland Zone and Corresponding Variable Subindex Score

Land Use Treatment	Score
Current Use	
Heavy grazing by livestock	0.10
Annual crop production	0.10
Moderate grazing by livestock	0.40
Mowed and hayed, but uncultivated field	0.50
Light grazing by livestock	0.65
Conservation easement with planting	0.75
Fallow, no cultivation or livestock >2 years, but <10 years	0.90
Managed as undisturbed grassland >10 years, but <20 years	0.95
Managed as undisturbed grassland >20 years	1.00
Projected Use	
Fill with paving	0.00
Fill without paving	0.05
Partial fill	0.10

Table 38
Current Land Use Treatment in the Wet Meadow, Shallow Marsh, and Deep Marsh Wetland Zones and Corresponding Variable Subindex Score

Land Use Treatment	Score
Current Use	
Heavy grazing by livestock	0.10
Dry year crop production	0.20
Moderate grazing by livestock	0.30
Mowed and hayed, but uncultivated field	0.40
Light grazing by livestock	0.60
Fallow, no cultivation or livestock >2 years, but <10 years	0.80
Managed as undisturbed grassland >10 years, but <20 years	0.95
Managed as undisturbed grassland >20 years	1.00
Projected Use	
Fill with paving	0.00
Fill without paving	0.05
Partial fill	0.10

Nearest Neighbor Distances (*$V_{WETPROX}$*). This variable is a measure of the proximity of similar wetlands (i.e., wetlands of the same HGM class) to the wetland being assessed. This is a critical landscape variable that affects the ability of species to move from one wetland to another. The variable is determined as the mean distance (m) between the assessment wetland and its closest five wetlands. This variable achieves a maximum score of 1 as the mean distance between wetlands approaches <100 m. Likewise, the Variable Subindex Score equals zero when the mean distance is ≥ 500 m.

$$MeanDist = \left[\frac{(Dist1) + (Dist2) + (Dist3) + (Dist4) + (Dist5)}{5} \right] \tag{31}$$

The Variable Subindex Score for $V_{WETPROX}$ is based on the relationship between the mean distance of the nearest five neighbors to the assessment wetland and the Variable Subindex Score illustrated in Figure 26.

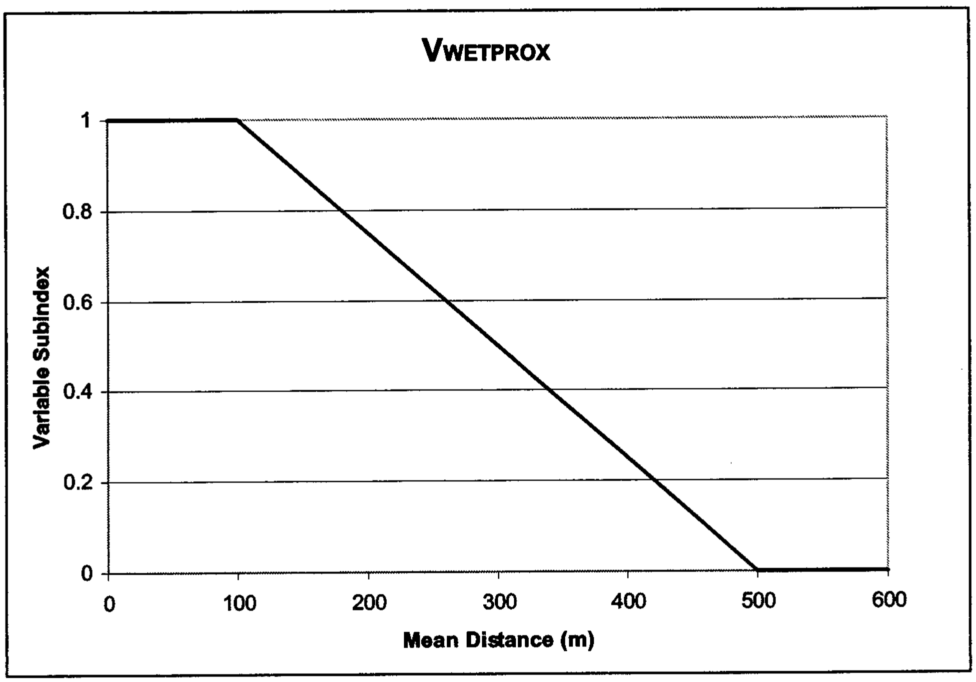

Figure 26. Relationship between Mean Distance of the Project Wetland to the five nearest neighbors and the Variable Subindex Score

Density of Wetlands (*V_{WETDEN}*). This variable is a measure of the density of wetlands as a percentage of the total area within an 800-m (0.5-mile) radius around the assessment wetland. Glacial potholes function within a larger landscape. Plant propagules, invertebrates, and vertebrates are dependent on movement of seeds or individuals from one wetland to another. For example, migratory waterfowl and wide-ranging large mammals have different home range requirements from those of small mammals and herptiles. This variable is

intended to capture the relative affinity of wetland density. Like $V_{WETPROX}$, this is a critical landscape variable that estimates the density of wetland habitat within an area that is relatively easy to access by large vertebrates and easily colonized by small vertebrates.

This variable may be estimated using Geographic Information Systems (GIS) and air photos or NWI maps, or the source maps and photos may be interpreted by other less sophisticated methods. Regardless of the mechanical approach taken, the objective is to estimate the overall percent coverage of wetland habitat within an ~ 800-m (0.5-mile) radius around the assessment wetland. This variable is scaled after the reference wetland areas of Ninepipe and the Ovando area pothole wetlands and is described by the relationship illustrated in Figure 27.

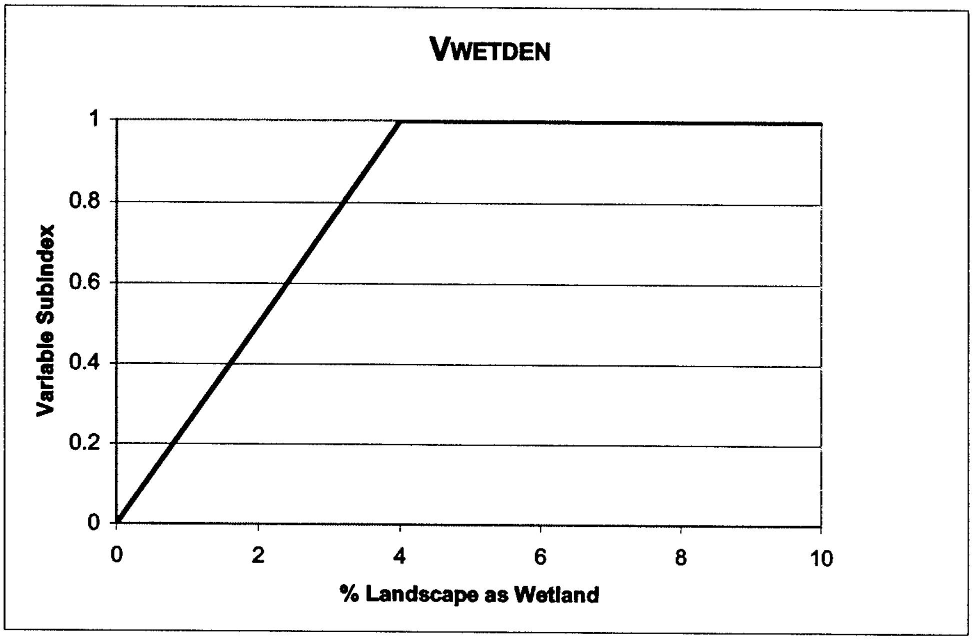

Figure 27. The relationship between the percentage of the landscape within an 800-m (0.5-mile) radius that is covered by wetland and the Variable Subindex Score

Geomorphic Modification (V_{GEOMOD}). This variable represents the anthropogenic modification of the geomorphic properties of the wetland through changes either to increase water storage or drain the wetland. Examples of geomorphic modification commonly practiced are tilling or ditching wetlands to remove water or dredging and excavating wetlands to increase water depth. Wetlands have been drained in the past most often so that the wetland can be cultivated and put into crop production. However, ditching or tilling may also have been done near home sites to drain the area for lawns or simply to reduce the standing water on the property.

The modification to the wetland is geomorphic in nature, but directly affects hydrologic properties. Filling, dredging, tilling, and ditching are all modifications

that change the fundamental character of the wetland. This variable is calculated as a function of change on a per-area basis and is linked to wetland zonation and vegetation communities (Table 39).

Table 39
Calculation Matrix of Undisturbed and Disturbed Hydrologic and/or Geomorphic Condition by Wetland Zone

To Wetland Zone \ From Wetland Zone	Upland/ Low Prairie	Wet Meadow	Shallow Marsh	Deep Marsh
Upland/ Low Prairie	1.0	0.1	0.0	0.0
Wet Meadow	0.8	1.0	0.8	0.5
Shallow Marsh	0.2	0.8	1.0	0.8
Deep Marsh	0.0	0.2	0.8	1.0

Functional Capacity Index

The assessment model for calculating the functional capacity index is as follows:

$$FCI = \left[\left(\frac{V_{UPUSE} + V_{EDGEUSE} + V_{WETUSE}}{3}\right) \times \left(\frac{V_{WETDEN} + V_{WETPROX}}{2}\right) \times V_{GEOMOD}\right]^{1/3} \quad (32)$$

In the model equation, the function of maintaining wetland interspersion and connectivity depends on the following factors: (a) land use in and immediately around the wetland, (b) wetland proximity and density on the landscape, and (c) modifications to wetland geomorphology resulting from direct impacts (e.g., tilling, ditching, excavation).

There are three subparts to the algorithm that describe this function. These three subparts are weighted equally by taking their geometric mean; thus if any one of these achieve a score of 0, the function is no longer occurring in the wetland. In the first part of the equation, the potential interspersion and connectivity are described by the land use variables within and around the wetland: V_{UPUSE}, V_{WETUSE}, and $V_{EDGEUSE}$. The second subpart of the equation is composed of the two landscape variables: V_{WETDEN} and $V_{WETPROX}$. These variables describe landscape positioning between and among wetlands. The third subpart is composed of the single variable describing the modification of wetland zonation through geomorphic change V_{GEOMOD}.

5 Assessment Protocols

Assessment Protocol Overview

Previous chapters of this Guidebook provided (a) background information on the HGM Approach, (b) wetland variables that are indicators of the level of function, (c) the assessment models consisting of those indicator variables, and (d) use of those indicators and models to describe level of function. This chapter provides the specific protocols that should be followed to conduct a functional assessment of Intermontane Prairie Pothole Wetlands. These protocols are designed for, and will generally be used within, the context of the permit review process under Section 404 of the Clean Water Act. They may also be used for any other wetland management goals or objectives (e.g., inventory, monitoring) that require independent measure of ecological function of Intermontane Prairie Pothole Wetlands.

The typical application of this Guidebook involves the examination of preproject conditions and forecasting of one or more postproject scenarios. To determine project impacts, the functional capacity of a wetland is assessed under preproject conditions and compared with the functional capacity under proposed postproject conditions. Data for the preproject assessment are normally collected under existing conditions, while data for the postproject assessment are normally based on predicted conditions. This chapter is organized into the three main steps necessary to conduct an HGM functional assessment using this Guidebook:

a. Preliminary tasks and assembly of preexisting data.

(1) Statement of purpose.

(2) Initial site characterization and collation of preexisting data.

(3) Screen for red flags.

(4) Defining the Wetland Assessment Area (WAA).

b. Collecting and recording data.

(1) Landscape and land use data.

(2) Hydrologic and geomorphic data.

(3) Soil data.

(4) Vegetation and habitat data.

c. Data entry and analysis.

(1) Data entry.

(2) Data analysis.

(3) Applying the results of the assessment.

Preliminary Tasks and Assembly of Preexisting Data

Statement of purpose

Begin the assessment process by unambiguously stating the purpose of the assessment. This statement will often be as simple as "The purpose of conducting this assessment is to determine how the proposed project will impact wetland functions." Other potential objectives could be to (a) compare several wetlands as part of alternatives analysis, (b) minimize project impacts, (c) document baseline conditions at the wetland site, (d) determine mitigation requirements, (e) determine mitigation success, or (f) determine the effects of a wetland management technique. A clear statement of the objectives will facilitate communication among the people conducting the assessment and will help to establish the approach taken in conducting the assessment. Of course, the specific approach will probably be different depending on whether the project is a Section 404 permit review, an Advanced Identification (ADID), Special Area Management Plan (SAMP), or some other purpose.

Initial site characterization and collation of preexisting data

Site characterization involves describing the project area in terms of climate, landform and geomorphic setting, hydrology, vegetation, soils, land use, groundwater features, surficial geology, urban areas, potential impacts, and any other relevant characteristics. The characterization should include a base map (USGS 7.5′ topographic quadrangle or suitable alternative) that shows the local scale topography, roads, ditches, buildings, streams, rivers, etc. Other maps and/or aerial photographs (e.g., NWI, Soil Survey) should be reviewed to obtain information on jurisdictional wetlands within the project boundaries, soil types, plant communities, and adjacent location of impacts. The following source materials and information are typically needed to provide an effective precharacterization of the wetland site to complete an assessment efficiently. This list does

not preclude use of other materials or information sources but rather provides a short list of the minimum source materials needed to characterize a site and complete the assessment. Following these initial steps in Site Characterization, immediately check for Red Flag conditions or features that may be inherent to the reference domain:

a. Topographic maps (1:24,000 and 1:100,000 scale) covering the wetland and the surrounding landscape (e.g., USGS Quadrangle maps).

b. National Wetlands Inventory maps (1:24,000 and 1:100,000 scale) covering the wetland and the surrounding landscape.

c. Aerial photographs (National Aerial Photography Program (NAPP), National High Altitude Photography (NHAP), or digital orthophotographs covering the wetland and the surrounding landscape.

d. Climatic records.

e. Hydrologic records.

f. Soil survey maps.

Screen for Red Flags

Red Flags are special features of a wetland or the surrounding landscape to which recognition or protection has been previously assigned. Screening for Red Flag features does not replace the execution of a functional assessment; however, if the assessment is being done within the context of a 404 permit review, identification of a Red Flag (e.g., an Endangered Species Act (ESA) listed endangered plant) may preclude approval of a permit. In other words, if a Red Flag condition or feature appears in a wetland, a functional assessment may not be necessary since consideration of that condition or feature may be so important that it becomes an overwhelming issue in consideration of the specific project and wetland impacts. For example, if a proposed project has the potential to impact a threatened or endangered species or habitat, an assessment of wetland functions may be unnecessary within the 404 permit review, since the project may be denied or modified strictly on the basis of impacts to that species or habitat. Of course, this does not preclude conducting a functional assessment, nor directly affect outcome of Functional Capacity calculations.

Defining the Wetland Assessment Area (WAA)

The WAA is the area of jurisdictional wetland within the proposed project area. If the WAA is physically continuous and relatively homogeneous and remains within the same HGM subclass appropriate for this Guidebook, it should be considered as a single WAA. (This will be the most frequent condition for this wetland type.) However, as the size of a project area increases, so do its heterogeneity and the likelihood that the WAA will encompass more than one

regional wetland subclass. If a WAA encompasses distinctly different wetland subclasses, regardless of whether they are a result of natural variability or anthropogenic alteration, then multiple WAAs should be designated and assessed separately. Whenever there are distinctly separate wetlands within a WAA, the WAA may be divided into distinct and spatially separated Partial Wetland Assessment Areas (PWAAs).

Collecting and Recording Data

Landscape and land use data

Wetland density in the landscape. Using a combination of USGS quadrangle maps, NWI maps, and aerial photographs, identify and delineate the density of wetlands within a radius of 800 m or 0.5 mile, whichever is most convenient depending on the scales available. If you have GIS capabilities, this can be easily accomplished using the digital NWI data available from the USFWS. If you do not have GIS capability, then other techniques may be used such as grid graph paper or counting the frequency of dots on acetate placed over the map. Regardless of the technique that you use to calculate areas, convert the landscape-scale wetland density into a percent of the total area within the required 800-m (0.5-mile) radius and enter this onto the Data Collection Form[1] titled "Landscape and Geomorphic Data." These data should be determined at the office following field ground truthing and general wetland delineation of the maps or aerial photographs.

Constructing an Onsite Base Map. Site characterization begins with the preparation of base maps for each WAA or PWAA. The development of accurate base maps is **critical to all subsequent calculations** integral to the assessment procedure and thus must be done accurately and precisely. There are two objectives in the development of the base maps: (a) determine the aerial extent of current land use treatments in and around the WAA, and (b) determine the aerial extent of the various wetland zones and associated vegetation communities and habitats. Base maps should initially be developed in the office from preexisting maps and/or photographs that were part of the initial site characterization (discussed in the previous section). You may have existing wetland delineation maps that have been done for the WAA, or such delineation can be integrated into this procedure.

At the field site, construct a site map that first delineates each wetland zone. Zones should be defined by a combination of hydrologic, soil, and vegetation characteristics (Figure 28) as part of wetland delineation following the "Corps of Engineers Wetlands Delineation Manual" (Environmental Laboratory (EL) 1987). The site map should be accurate to within ±1 m. This may be accomplished using a variety of field instruments as simple as a meter tape or as complex as a laser total station for detailed surveying work (Figure 29). As you measure the

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[1] Data Collection Forms are included in Appendix C.

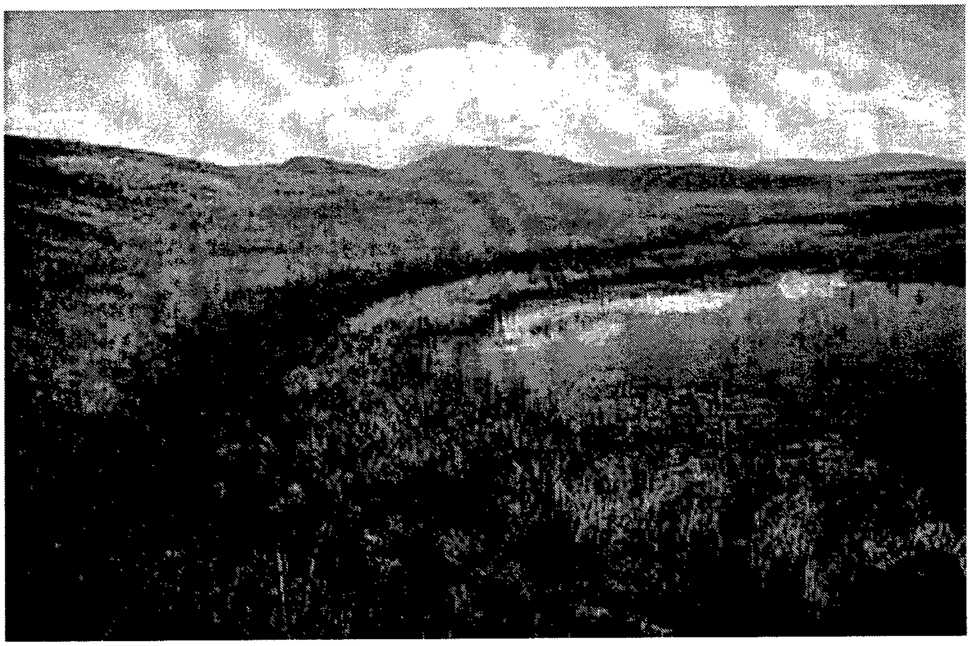

Figure 28. A permanently flooded pothole wetland near Ovando, Montana. Note the distinct banding of vegetation and wetland zones. The upland is distinctly dry with less dense vegetation. The Low Prairie wetland zone is never inundated, but the vegetation and soils show distinct characteristics of influence from subsurface moisture gradient reaching to the root zone. The Wet Meadow wetland zone is characterized by a deep green band of vegetation, primarily *Carex rostrata* and *Juncus balticus*. The shallow marsh in this wetland is characterized by extended inundation and dominated by tall emergent vegetation, primarily *Carex nebraskensis*. The deep marsh wetland zone is characterized by only a few emergent plants, but largely open water with submerged vegetation

various distances, transfer them to the base map. Draw the base map to scale on graph paper or any other grid paper that aids in the accuracy of the map. Use the aerial photographs and NWI maps assembled during the initial site characterization and collation of preexisting data discussed previously. A typical base map is shown in Figure 30.

On the site map draw to scale each wetland zone, including the Low Prairie. The wetland is defined as the jurisdictional wetland (based on EL 1987) and contains one or more of the vegetation zones: Wet Meadow, Shallow Marsh, and Deep Marsh (after Stewart and Kantrud 1972). For this Guidebook these vegetation zones are considered to be, under most circumstances, synonymous with the seasonal, semipermanent, and permanent wetland zones, respectively, defined by Cowardin et al. (1979). Three wetland types generally may be described within the Intermontane Prairie Pothole Wetland subclass: Type I, those having a wet meadow only; Type II, those having a wet meadow and a shallow marsh; and Type III, those having a wet meadow, a shallow marsh, and a deep marsh (Figure 31).

Figure 29. Proper placement of either a theodolite survey total station or an autolevel. Either of these instruments will greatly aid in rapid acquisition of needed geomorphic data

The Low Prairie is defined as the vegetation community or communities surrounding the wetland that are influenced by soil moisture from the wetland, but do not meet jurisdictional wetland criteria. The Low Prairie will often consist of a single vegetation community ringing the pothole wetland. This zone is characterized by primarily upland plant species that are distinctly more robust with clear evidence of good soil moisture. The lower elevation edge of the Low Prairie, which also marks the high-elevation edge of the Wet Meadow wetland zone, is generally distinct with the initiation of hydric soil and wetland vegetation characteristics as described in EL (1987). The upper boundary of the Low Prairie is generally less well defined since the transition from Low Prairie to Upland is often tapered, and distinct boundaries are difficult to identify with precision. The decision on the delineation of the Low Prairie–Upland boundary comes with experience and will vary slightly across the reference domain.

Likewise, each wetland zone is delineated, then drawn on the base map following the zonation of Stewart and Kantrud (1972). Each wetland zone is further subdivided into vegetation communities. For example, the shallow marsh may contain a large patch of cattails (*Typha latifolia*) at one end of the zone, while the remainder of the zone is occupied by water smartweed (*Polygonum amphibium*) (Figure 30). On occasion a vegetation community may cross wetland zone boundaries. Wetland zone boundaries take precedence over the vegetation community boundaries; thus the single vegetation community is identified as being two separate communities based on being in two wetland zones.

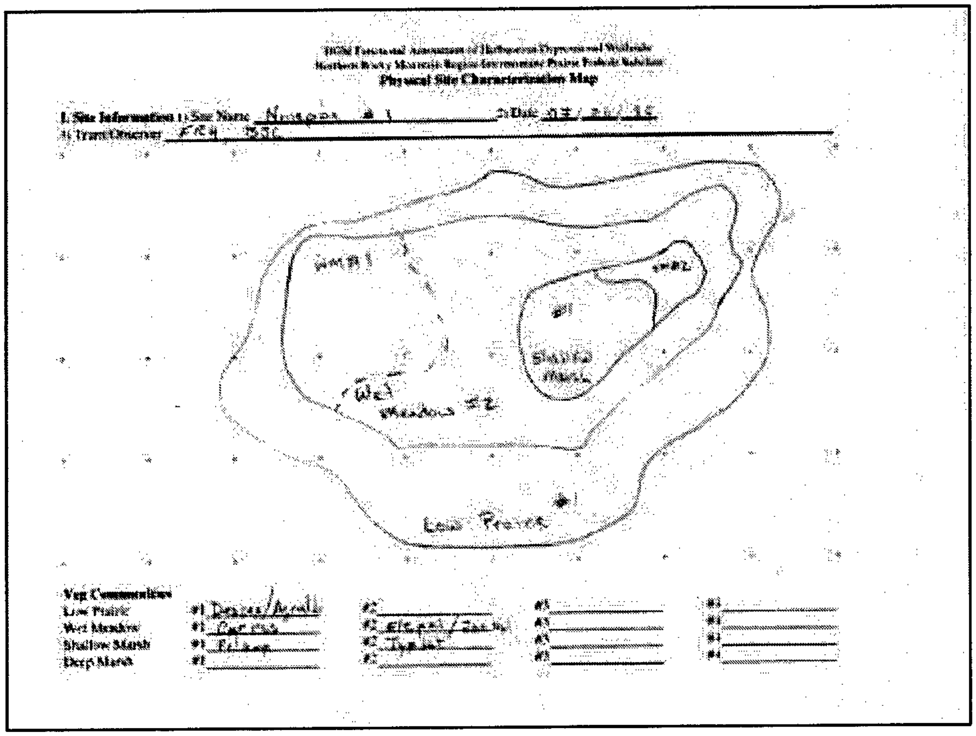

Figure 30. Illustration of the onsite characterization map used in this Guidebook. Note that the Low Prairie is composed of a single-community type dominated by *Deschampsia cespitosa* and *Agrostis alba*. The Wet Meadow has two vegetation types: #1, composed of *Carex rostrata,* and #2, composed of *Eleocharis palustris* and *Juncus balticus.* The Shallow Marsh also has two vegetation communities dominated by #1, *Polygonum amphibium,* and #2, *Typha latifolia*

After drawing and labeling each of the wetland zones and then drawing and labeling the vegetation communities on the base map, **calculate the surface area** (m^2) of each vegetation community by wetland zone. Record the total area within the Low Prairie–Upland Boundary, then record the area of each wetland zone and the area of each vegetation community within those zones on the Data Collection Form titled "Landscape and Land Use Data." Surface areas may be calculated using any of numerous available methods. For example, after the site visit, you may use a digitizing pad and computer at the office to determine areas. On the other hand, if such technology is not available, then less sophisticated techniques that have been used for decades may be employed. If the site maps have been drawn on graph paper, then count the number of squares within each vegetation community or use the dot matrix on acetate technique.

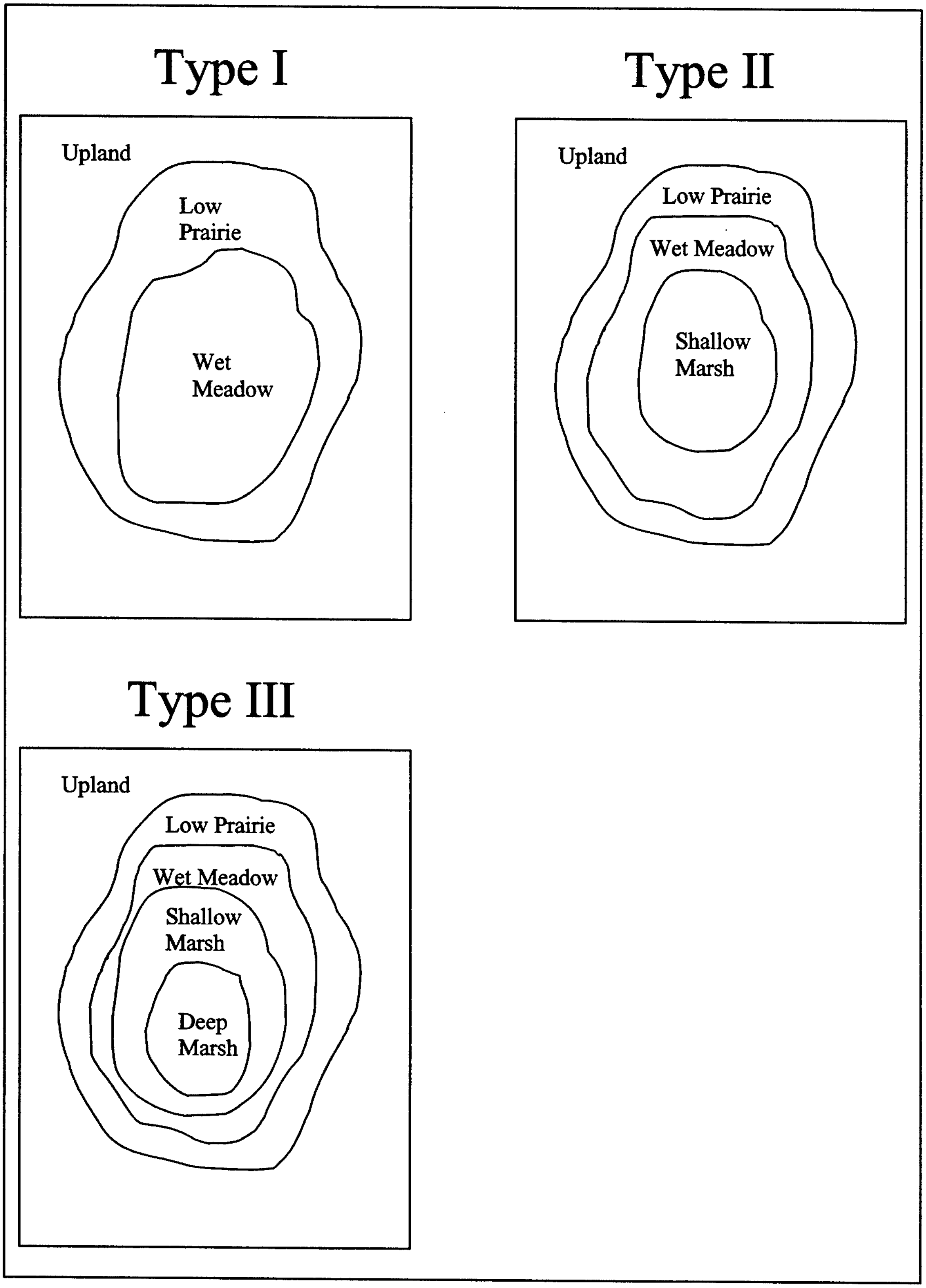

Figure 31. Wetland types and zonation of intermontane prairie potholes. Each zone expresses specific water regime, soil, and vegetation characteristics

Current land use data. Within the wetland catchment there may be several different land use treatments affecting wetland function, or all the various wetland zones and vegetation communities may be receiving a single land use treatment. In this Guidebook, "land use treatment" refers to a categorical range of uses and management prescriptions. Using Tables 40–42, determine the appropriate land use treatment for each vegetation community in the upland, Low Prairie, Wet Meadow, Shallow Marsh, and Deep Marsh. Enter the corresponding score for each vegetation community on the Data Collection Form titled "Landscape and Land Use Data" based on the appropriate corresponding land use treatment table and wetland zone.

Distance to nearest neighbors. Measure the proximity of the project wetland (WAA) to surrounding wetlands from either the USGS or NWI maps or at the field site, depending on what is appropriate for the scale and the distance between wetlands. For example, if the distances are <100 m, then the appropriate method of measurement is in the field with a measuring tape. However, if the nearest neighbors are >100 m, then it may be more appropriate to make the measurements from the maps.

The measurements to be made are from the Low Prairie and Wet Meadow boundary of the project wetland to the same boundary of the nearest five wetlands, taking the shortest distance between wetlands in each measurement, as illustrated in Figures 32 and 33. Enter these data on the Data Collection Form titled "Landscape and Land Use Data."

Table 40
Current Land Use Treatment in the Upland and Corresponding Variable Subindex Score

Current Land Use Treatment	Score
Commercial right-of-way or paved driveway	0.00
Private right-of-way or unpaved driveway	0.10
Heavy grazing by livestock	0.20
Annual crop production	0.20
Generalized soil disturbance	0.30
Residential or commercial lawn	0.40
Moderate grazing by livestock	0.50
Mowed and hayed, but uncultivated field	0.60
Light grazing by livestock	0.70
Conservation easement with planting	0.85
Fallow, no cultivation or livestock >2 years, but <10 years	0.90
Managed as undisturbed grassland >10 years, but <20 years	0.95
Managed as undisturbed grassland >20 years	1.00

Table 41 **Current Land Use Treatment in the Low Prairie Wetland Zone and Corresponding Variable Subindex Score**	
Land Use Treatment	**Score**
Current Use	
Heavy grazing by livestock	0.10
Annual crop production	0.10
Moderate grazing by livestock	0.40
Mowed and hayed, but uncultivated field	0.50
Light grazing by livestock	0.65
Conservation easement with planting	0.75
Fallow, no cultivation or livestock >2 years, but <10 years	0.90
Managed as undisturbed grassland >10 years, but <20 years	0.95
Managed as undisturbed grassland >20 years	1.00
Projected Use	
Fill with paving	0.00
Fill without paving	0.05
Partial fill	0.10

Table 42 **Current Land Use Treatment in the Wet Meadow, Shallow Marsh, and Deep Marsh Wetland Zones and Corresponding Variable Subindex Score**	
Land Use Treatment	**Score**
Current Use	
Heavy grazing by livestock	0.10
Dry-year crop production	0.20
Moderate grazing by livestock	0.30
Mowed and hayed, but uncultivated field	0.40
Light grazing by livestock	0.60
Fallow, no cultivation or livestock >2 years, but <10 years	0.80
Managed as undisturbed grassland >10 years, but <20 years	0.95
Managed as undisturbed grassland >20 years	1.00
Projected Use	
Fill with paving	0.00
Fill without paving	0.05
Partial fill	0.10

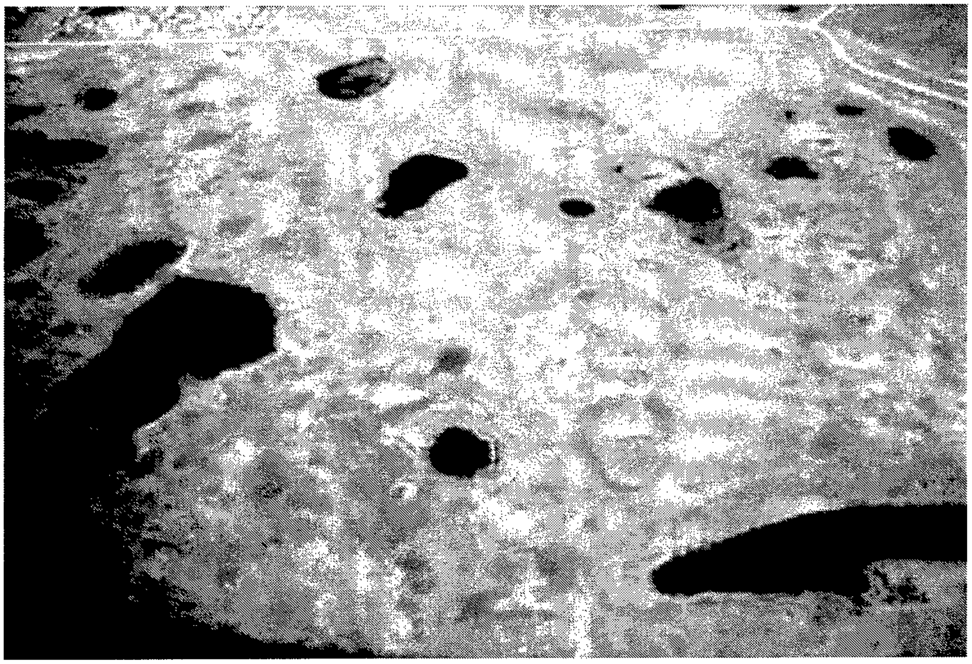

Figure 32. Aerial photo of the pothole area near Ninepipe, Montana. Note the high concentration of wetlands in the region and the diversity of pothole wetland types. Wetland density in this area is greater than 4 percent of the landscape. Distances should be measured between the project wetland and the five nearest neighboring wetlands, as illustrated in Figure 33

Hydrologic and geomorphic data

Catchment size and slope. Generally, Intermontane Prairie Pothole wetlands have relatively small catchments surrounding the wetland basin. Establish four transects, two along the long axis and two along the lateral axis of the wetland, from the outer edge of the Wet Meadow zone to the catchment edge as illustrated in Figure 34. Label each transect a, b, c, or d. Measure the total length of each transect and the change in elevation over the total length measured. Record the data on the Data Collection Form titled "Hydrologic and Geomorphic Data."

Hydrologic modifications. Estimate the number of weeks each year the wetland is inundated with water across most of the central and deepest part of the wetland. This is best accomplished by having a clear knowledge of the WAA annual hydrograph. However, when site-specific data are not available, use a combination of soil and vegetation indicators and the wetland and deepwater classification of Cowardin et al. (1979) summarized in Table 43 to estimate the number of weeks of wetland flooding.

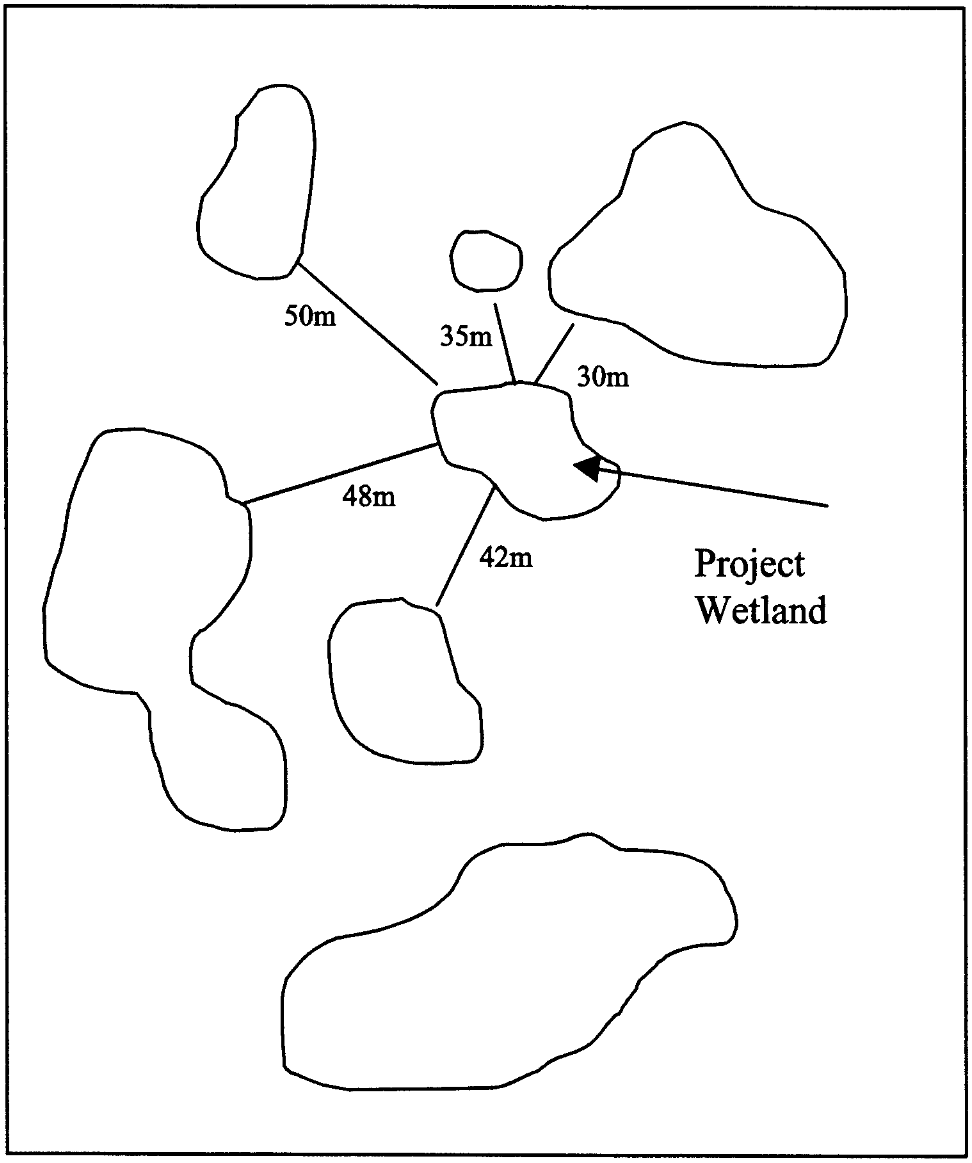

Figure 33. Measuring the five nearest neighbors to a project wetland. Measurements extend between upper Wet Meadow boundaries

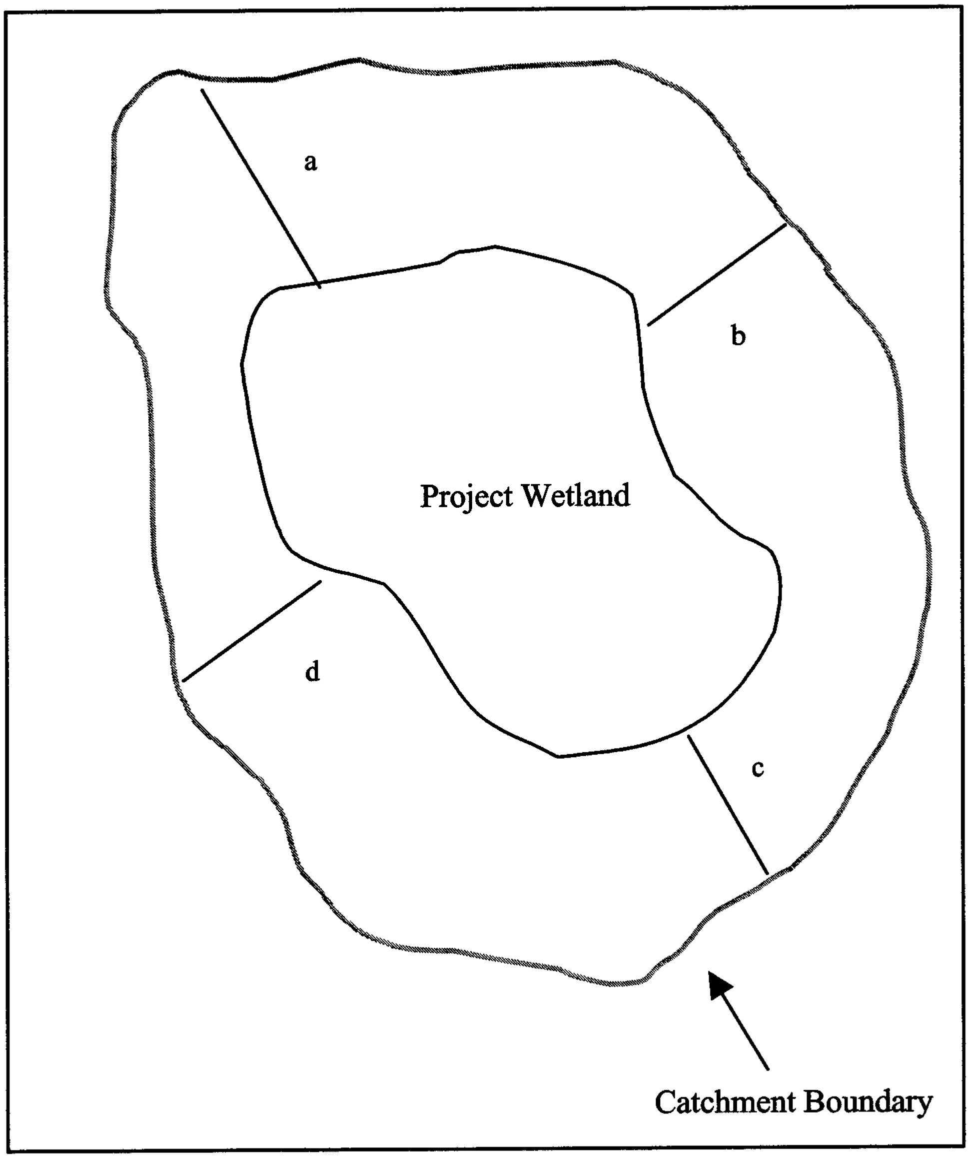

Figure 34. A wetland, its catchment boundary, and typical arrangement of four transects (*a-d*) for measuring catchment size and slope

Table 43
Duration of Wetland Flooding with Cowardin et al. (1979) Water Regime

Flooding Condition	Weeks Flooded	Water Regime
Temporarily flooded	1 - 4	A
Seasonally flooded	5 - 17	C
Semipermanently flooded	18 - 40	F
Intermittently exposed	41 - 51	G
Permanently flooded	52	H

Determine the normative flooding condition, (i.e., the number of weeks of the year the wetland floods in an unaltered condition) and thus the Cowardin Water Regime. Calculate the Variable Subindex Score through use of the Cowardin Water Regime Matrix table (Table 44). After determining the Water Regime under Normative conditions, locate the appropriate corresponding letter designation at the top of the matrix (i.e., A, C, F, G, or H). Based on project-specific disturbance, determine the altered water regime that would be expected

Table 44
Matrix of Cowardin Water Regime in Which Subindex Scores Are Established by Determining the Normative and Altered Water Regimes

Normative Cowardin Water Regime

Altered Cowardin Water Regime	A	C	F	G	H
A	1.0	0.7	0.5	0.2	0.1
C	0.7	1.0	0.7	0.5	0.2
F	0.5	0.7	1.0	0.7	0.5
G	0.2	0.5	0.7	1.0	0.7
H	0.1	0.2	0.5	0.7	1.0

after the project is completed. Locate this water regime letter designation along the left side of the matrix. The subindex score for the variable $V_{HYDROMOD}$ is the intersection on the matrix table. Enter the current subindex score for current conditions on the Data Collection Form titled "Hydrologic and Geomorphic Data."

Two examples using the matrix follow:

a. *Example 1:* The wetland on which you are conducting a functional assessment is an unaltered wetland that you estimate has a normative water regime of 30 weeks of flooding, (Normative Water Regime F). The project will result in the diversion of water away from the wetland, and you estimate that the duration of flooding will be reduced to 12 weeks (Altered Water Regime C). The subindex score for the current condition is 1.0 and the postproject Subindex score is 0.7.

b. *Example 2:* The wetland on which you are conducting a functional assessment has already been altered. In a normative condition the wetland had an intermittently exposed water regime with flooding of 40-45 weeks per year (Normative Water Regime G), but in its current condition it is only temporarily flooded for 2-4 weeks (Altered Water Regime A). The subindex score for the current condition is 0.2.

Geomorphic modifications. This variable represents the anthropogenic modification of the geomorphic properties of the wetland through modifications of wetland basin depth, either increasing or decreasing specific wetland zones. Examples of geomorphic modification commonly practiced are tilling or ditching wetlands to remove water, filling wetlands, or dredging and excavating wetlands to increase water depth. Wetlands have been drained most often in the past to increase cultivated land so that it can be put into crop production. However, ditching or tilling may also have been done near home sites to drain the area for lawns or simply to reduce the standing water on the property.

The modification to the wetland is geomorphic, but directly affects hydrologic properties. Filling, dredging, tilling, and ditching are all modifications that change the fundamental character of the wetland. Use the same data used to develop the onsite base map, discussed previously, to draw and label each of the wetland zones. **Calculate the surface area** (m^2) of each wetland zone. Record the total area of the Low Prairie, Wet Meadow, Shallow Marsh, and Deep Marsh on the Data Collection Form titled "Hydrologic and Geomorphic Data." For an unaltered wetland, the subindex score for the variable V_{GEOMOD} is 1.0 for each of the wetland zones. For an altered wetland, multiply the area of each zone by the subindex score taken from the calculation matrix found in Table 45. For example, if a project will result in dredging and conversion of wet meadow to deep marsh, the subindex score is 0.2, which is then multiplied by the area of wet meadow that is being altered. Divide subindex scores multiplied by the area of each wetland zone or area being converted the total area of the wetland to achieve a total subindex score for the variable.

Table 45
Calculation Matrix of Subindex Scores Based on Unaltered and Altered Geomorphic Conditions by Wetland Zone

Altered Wetland Zones \ Unaltered Wetland Zones	Low Prairie	Wet Meadow	Shallow Marsh	Deep Marsh
Low Prairie	1.0	0.1	0.0	0.0
Wet Meadow	0.8	1.0	0.8	0.5
Shallow Marsh	0.2	0.8	1.0	0.8
Deep Marsh	0.0	0.2	0.8	1.0

Soil data

Soil profiles. A soil profile "pit" will be needed for each of the wetland zones, the Low Prairie, and the Upland. You may dig soil pits with a "sharp-shooter" shovel or a soil auger. However, if you use an auger, you must be able to measure horizon depths and separate horizons to distinguish hue and chroma of selected horizons clearly.

The soil data needed for completing a functional assessment using this Guidebook are summarized in Table 46. A review of this table shows that the soil pit in the Wet Meadow needs to extend to the C horizon; however, all other pits need to extend only to the top of the B horizon.

Table 46
Summary of Soil Data Required for Completing a Functional Assessment of Intermontane Prairie Pothole Wetlands

S/K Zones	Depth of O	Depth of A	Hue of A	Chroma of A	Texture of A	Texture of C
Upland						
Low Prairie						
Wet Meadow						
Shallow Marsh						
Deep Marsh						

Soil texture. Use the Soil Texture Triangle illustrated in Figure 35 to determine the percent clay, silt, or sand present in the A horizon of the Upland soil and the C Horizon of the Wet Meadow soil. Assign the soil to one of 12 basic textural classes. Based on the textural class in Figure 35, obtain a soil texture score in Table 47. Enter the score from Table 47 for each of the two soil texture determinations required (i.e., A horizon of the Upland soil and the C horizon of the Wet Meadow soil) on the Data Collection Form titled "Soil Data." Based on the textural class obtained in Figure 35, look up the Erodibility Index Score for the Upland A horizon soil. Likewise, enter this Erodibility Index Score on the Data Collection Form titled "Soil Data."

Soil depth. Measure the depths of the O horizon (cm) and the A horizon (cm) from soil pits in the Low Prairie, Wet Meadow, Shallow Marsh, and Deep Marsh. Generally, the Shallow Marsh and Deep Marsh zones are inundated with water; thus it may be easier to measure the depth of the O and A horizons using a soil auger or soil probe. Record these data on the Data Collection Form titled "Soil Data."

Soil color. Using a Munsell Color Chart, determine the hue and chroma of the A horizon from the Wet Meadow soil profile. After determination of the hue value, assign a numeric score based on Table 48. Enter the hue score from Table 48 and the chroma value from the Munsell Color Chart on the Data Collection Form titled "Soil Data."

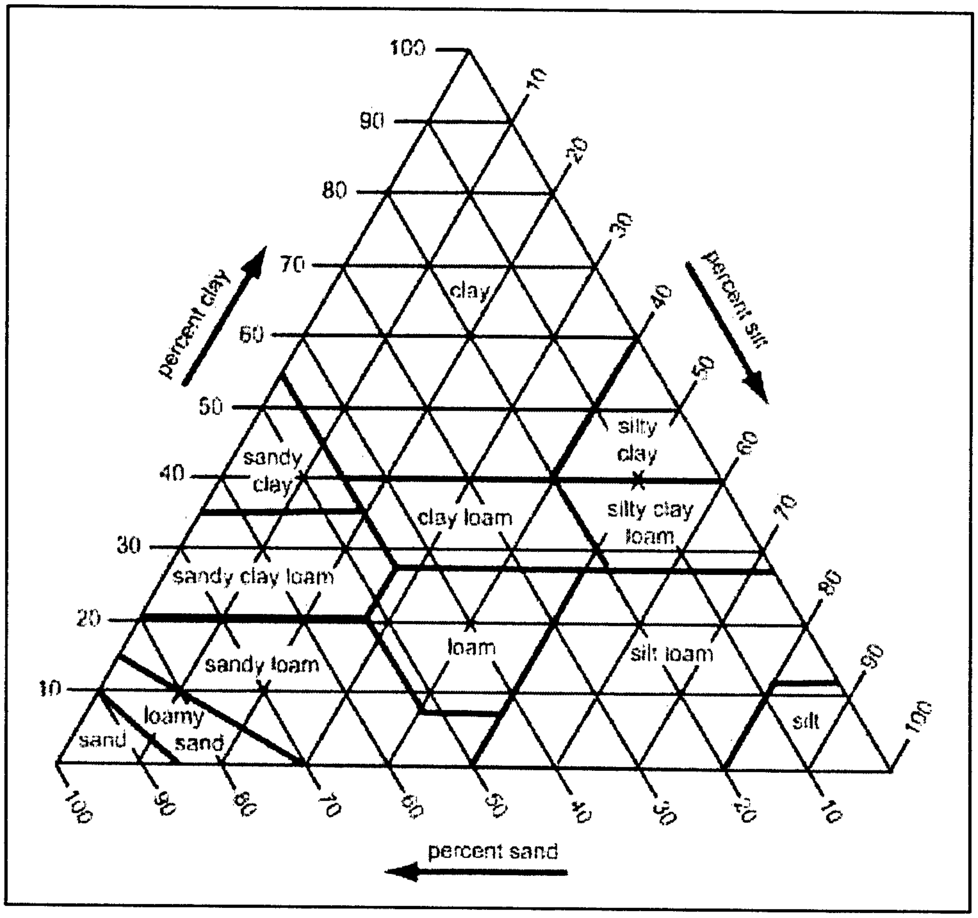

Figure 35. Chart showing the percentages of clay, silt, and sand in the basic soil textural classes

Table 47
Soil Texture and Corresponding Texture Index Score and Erodibility Index Score for 12 Soil Texture Classes and Gravel

Soil Texture	Texture Index Score	Erodibility Index Score
Gravel	0.00	0.000
Sand	0.33	0.001
Loamy sand	0.42	0.003
Sandy loam	0.50	0.006
Sandy clay loam	0.58	0.007
Loam	0.67	0.010
Silt loam	0.75	0.018
Silt	0.83	0.034
Sandy clay	0.92	0.009
Clay loam	1.00	0.014
Silty clay loam	1.00	0.030
Silty clay	1.00	0.041
Clay	1.00	0.020

Table 48
Hue Value and Corresponding Score Based on Munsell Color Chart

Munsell Hue	Score
2.5YR	17.5
5YR	15.0
7.5YR	12.5
10YR	10.0
2.5Y	7.5
5Y	5.0
N	2.5
GY G GB or B	0.0

Vegetation and habitat data

Collect vegetation and habitat data after all other field data have been collected. This will maximize familiarity with the site before this segment of the assessment is evaluated. Each vegetation community identified and drawn on the Onsite Base Map in the protocol segment **(Landscape and Land Use Data)** must be included in the vegetation sampling. Use a single "Vegetation and Habitat Data" Collection Form for each vegetation community. Each plant community must be characterized by community composition and coverage, stem density, and the native/nonnative species mix. In the field, enter these data on "Vegetation Community Field Data" Collection Forms. These data are used to fill in the Data Collection Form "Vegetation and Habitat Data."

Plant species composition and coverage. Within **each** vegetation community select three sample sites at stratified-random locations. It is important to remember that the objective of the assessment is to characterize the wetland, not to describe the extent of variation. Therefore, when selecting the stratified-random locations for sampling, select plot sites that represent the vegetation community being sampled. Using a 1-m^2 plot, identify and estimate the percent coverage of all plant species that compose a coverage exceeding 1 percent of the total coverage (Figure 36). List all species with their estimated percent coverage on the "Vegetation and Habitat Data" Collection Forms. In addition to the species obtained from the three sample plots, add any other species to the species list that occurs within the vegetation community. Using the species list provided (Table 49), identify each species and list as being native (N) or nonnative (E).

Figure 36. Using a 1-m^2 plot sampler for making plant coverage estimates. The sampler is working along the edge of the shallow marsh

Plant stem density. Plant stem density is measured within each vegetation community using either a 0.1-m^2 or a 0.25-m^2 subplot taken from within each of the 1-m^2 plots used for estimating coverage. The size of the stem density subplot will depend on the density of the plants. If there are fewer than 25 stems within the 0.1-m^2 subplot, then the 0.25-m^2 subplot should be used. Count the number of plant stems, regardless of species, within each subplot and record the data on the "Vegetation and Habitat Data" Collection Form.

Data Entry and Analysis

Data entry

Following the Assessment Protocols discussed in this chapter, complete the wetland functional assessment by being certain that you have acquired all necessary data. It is critical that all data entry is made on the Site Characterization and various Field Data Collection Forms provided with this Guidebook. This will greatly reduce confusion about what data need to be collected and will help prevent accidentally skipping necessary field data while you visit the Wetland Assessment Area. Much of the initial site characterization and map data will come from preexisting databases, Internet library sources (e.g., USGS, Natural Resource Information System (NRIS)) or office source materials (e.g., NWI maps, county soil survey maps). Collation of these materials and analysis of landscape variables generally done in the office will require about 1 hour. Collection of field data for a single Intermontane Pothole Wetland of moderate size

Table 49
Species List of Common Vegetation in Intermontane Prairie Pothole Wetlands in the Northern Rocky Mountains, with Reference to Scientific Name, Common Name, and Native/Non-native Status

Species Name	Native or Exotic[1]	Common Name
Achillea millefolium	N	Common Yarrow
Agoseris glauca	N	Pale Agoseris
Agropyron caninum	N	Bearded Wheatgrass
Agropyron smithii	N	Western Wheatgrass
Agrostis alba	E	Redtop
Agrostis scabra	N	Tickle-grass
Alisma gramineum	N	Narrowleaf Waterplantain
Alisma plantago-aquatica	N	Small-flowered Waterplantain
Alopecurus aequalis	N	Short-awn Foxtail
Anaphalis margaritacea	N	Common Pearly-everlasting
Antennaria rosea	N	Rosy Pussy-toes
Artemisia ludoviciana	N	Prairie Sagewort
Aster occidentalis	N	Western Aster
Aster pansus	N	Tufted White Prairie Aster
Astragalus adsurgens	N	Standing Milk-vetch
Bromus inermis	E	Smooth Brome
Bromus japonicus	E	Japanese Brome
Bryophyte species	N	Moss species
Calamagrostis inexpansa	N	Northern Reedgrass
Callitriche heterophylla	N	Different-leaved Water-starwort
Callitriche verna	N	Spring Water-starwort
Carex aperta	N	Columbia Sedge
Carex atherodes	N	Awned Sedge
Carex athrostachya	N	Slender-beaked Sedge
Carex aurea	N	Golden Sedge
Carex douglasii	N	Douglas's Sedge
Carex lanuginosa	N	Wooly Sedge
Carex lasiocarpa	N	Slender Sedge
Carex nebrascensis	N	Nebraska Sedge
Carex pachystachya	N	Thick-headed Sedge
Carex praegracilis	N	Clustered Field Sedge

(Sheet 1 of 4)

[1] N = native, E = Nonnative (exotic), and U = unknown status.

Table 49 (Continued)		
Species Name	**Native or Exotic**	**Common Name**
Carex rostrata	N	Beaked Sedge
Carex sartwellii	N	Sartwell's Sedge
Carex vesicaria	N	Inflated Sedge
Centaurea Maculosa	E	Spotted Knapweed
Centunculus minimus	N	Chaffweed
Cirsium arvense	E	Canada Thistle
Cirsium vulgare	E	Bull Thistle
Crepis runcinata	N	Meadow Hawksbeard
Deschampsia cespitosa	N	Tufted Hairgrass
Eleocharis acicularis	N	Needle Spike-rush
Eleocharis palustris	N	Common Spikesedge
Epilobium glaberrimum	N	Smooth Willow-herb
Epilobium paniculatum	U	Autumn Willow-herb
Epilobium watsonii	N	Watson's Willow-herb
Equisetum arvense	N	Field Horsetail
Equisetum laevigatum	N	Smooth Scouring-rush
Erigeron lonchophyllus	N	Spear-leaf Fleabane
Fragaria vesca	N	Woods Strawberry
Galium multiflorum	N	Many-flowered Bedstraw
Galium trifidum	N	Small Bedstraw
Geranium viscosissimum	N	Sticky Geranium
Glyceria borealis	N	Northern Mannagrass
Gnaphalium palustre	N	Low Cudweed
Grindelia howellii	N	Howell's Gumweed
Helenium autumale	N	Sneezeweed
Hippuris vulgaris	N	Common Mare's-tail
Hordeum brachyantherum	N	Meadow Barley
Hordeum jubatum	N	Foxtail Barley
Hypericum formosum	N	Western St. John's-wort
Iris missouriensis	N	Rocky Mountain Iris
Juncus articulatus	N	Jointed Rush
Juncus balticus	N	Baltic Rush
Juncus ensifolius	N	Dagger-leaf Rush
Juncus tenuis	N	Slender Rush
Koeleria macrantha	N	Prairie June grass
Lactuca serriola	E	Prickly Lettuce
		(Sheet 2 of 4)

Table 49 (Continued)		
Species Name	**Native or Exotic**	**Common Name**
Lemna minor	N	Water Lentil
Linaria vulgaris	E	Butter-and-eggs
Lysimachia ciliata	N	Fringed Loosestrife
Mentha arvensis	N	Field Mint
Microseris gracilis	N	Pink Microseris
Muhlenbergia asperifolia	N	Alkali Muhly
Muhlenbergia richardsonis	N	Mat Muhly
Myriophyllum spicatum	N	Spiked Water-milfoil
Nitella species	N	Nitella species
Oenothera strigosa	N	Common Evening-primrose
Orthocarpus luteus	N	Yellow Owl-clover
Penstemon species	N	Penstemon Species
Phalaris arundinacea	E	Reed Canary grass
Phleum pratense	E	Common Timothy
Poa compressa	E	Canada Bluegrass
Poa palustris	E	Fowl Bluegrass
Poa pratensis	E	Kentucky Bluegrass
Polygonum amphibium	N	Water Smartweed
Populus tremuloides	N	Quaking Aspen
Populus trichocarpa	N	Black Cottonwood
Potamogeton foliosus	N	Leafy Pondweed
Potamogeton gramineus	N	Grass-leaved Pondweed
Potamogeton natans	N	Floating-leaved Pondweed
Potamogeton pectinatus	N	Fennel-leafed Pondweed
Potamogeton richardsonii	N	Richardson's Pondweed
Potentilla aguta	N	Tall Cinquefoil
Potentilla anserina	N	Common Silverweed
Potentilla biennis	N	Biennial Cinquefoil
Potentilla gracilis	N	Slender Cinquefoil
Prunella vulgaris	E	Self-heal
Ranunculus acriformis	N	Sharp Buttercup
Ranunculus aquatilis	N	White Water-buttercup
Ranunculus cymbalaria	N	Shore Buttercup
Ranunculus flammula	N	Creeping Buttercup
Rorippa curvisiliqua	N	Western Yellowcress
Rosa woodsii	N	Woods Rose
		(Sheet 3 of 4)

Table 49 (Concluded)		
Species Name	**Native or Exotic**	**Common Name**
Rumex crispus	E	Curly Dock
Rumex maritimus	N	Golden Dock
Sagittaria cuneata	N	Arumleaf Arrowhead
Salix bebbiana	N	Bebb Willow
Salix drummondiana	N	Drummond Willow
Scirpus acutus	N	Hardstem Bulrush
Sisymbrium altissimum	E	Tumble mustard
Sisyrinchium angustifolium	N	Blue-eyed Grass
Sium suave	N	Hemlock Water-parsnip
Solidago canadensis	N	Canada Goldenrod
Sparganium emersum	N	Simplestem Bur-reed
Stachys palustris	N	Swamp Hedge-nettle
Stellaria longipes	N	Longstalk Starwort
Taraxacum officinale	E	Common Dandelion
Tragopogon dubius	E	Goat's Beard
Trifolium repens	E	White Clover
Typha latifolia	N	Common Cattail
Utricularia vulgaris	N	Common Bladderwort
Veronica peregrina	N	Pursland Speedwell
Veronica scutellata	N	Marsh Speedwell
Viola nephrophylla	N	Northern Bog Violet
		(Sheet 4 of 4)

(<2–3 acres) and complexity (six to eight vegetation communities) will generally require one person 2–4 hours or two people 1–2 hours to complete. This may require more time initially, but experience with the assessment procedure will reduce the required time to the lower end of this range.

Data Analysis

The primary objective of the HGM Approach to the Functional Assessment of Wetlands is the determination of FCI, which when combined with Area produces a Functional Capacity Unit. The Functional Capacity Unit, in turn, provides a basis for determination of impact and mitigation (Smith et al. 1995). This Guidebook illustrates three methods of analyzing the data collected to complete the functional assessment.

Manual determination of FCI. After collection of all data and the completion of the Site Characterization and Field Data Forms, fill out the FCI

Worksheet provided in Appendix C. The FCI Worksheet prompts the user to determine Variable Subindex Scores corresponding with each variable. The Variable/Metric to Variable Subindex Score relationships are based on the reference wetland data set collected during the development of this Guidebook. The Variable Subindex Scores are employed in the 7 Functional Capacity Index algorithms discussed and explained in Chapter 4 and Appendix B of the Guidebook. The Guidebook user can then determine, by hand calculation, the FCI and Functional Capacity Units of each function.

Computer determination of FCI. After collection of all data and the completion of the Site Characterization and Field Data Forms, open the computer file <IMPPotholeFCI.xls> of the FCI at *http://www.wes.army.mil/el/wetlands/hgmhp.html*. The computer program is written in Microsoft Excel but can also be run by other compatible software packages. Using the Field Data Forms, complete each worksheet page found in the computer file. When all the required data have been entered, the program will automatically calculate each variable subindex score. The program will also calculate the FCI scores for each function.

Applying the results of the assessment

Once the assessment and analysis phases are complete, these results can be used to compare the same wetland assessment area at different points in time, compare different wetland assessment areas at the same point in time, compare different alternatives to a project, or compare different HGM classes or subclasses per Smith et al. (1995) and Davis (in preparation, Chapter 8).

Users of this Guidebook must keep in mind that HGM functional assessment is a tool to be used toward better understanding of wetland ecosystem function. FCIs provide specific metrics that may be used to calculate degree of functional impairment or functional improvement. It can dramatically assist the wetland scientist to inventory, monitor, and determine ecological health of a wetland. It can also assist wetland regulators in the implementation of policy. It will not, however, replace the fundamental decision-making processes necessary to establish policy. It also requires an understanding of foundational principles in wetland ecology and can be adequately and appropriately applied only by well-trained wetland ecologists and scientists.

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Appendix A Glossary

A Horizon: A mineral soil horizon at the soil surface or below an O horizon characterized by accumulation of humified organic matter intricately mixed with the mineral fraction.

Assessment Model: A simple model that defines the relationship between ecosystem and landscape scale variables and functional capacity of a wetland. The model is developed and calibrated using reference wetlands from a reference domain.

Assessment Objective: The reason for an assessment of wetland functions. Assessment objectives normally fall into one of three categories: documenting existing conditions, comparing different wetlands at the same point in time (e.g., alternatives analysis), and comparing the same wetland at different points in time (e.g., impact analysis or mitigation success).

Assessment Team (A-Team): An interdisciplinary group of regional and local scientists responsible for classification of wetlands within a region, identification of reference wetlands, construction of assessment models, definition of reference standards, and calibration of assessment models.

Channel: A natural stream or river, or an artificial feature such as a ditch or canal that exhibits features of bed and bank, that conveys water primarily unidirectionally downgradient.

Direct Impacts: Project impacts that result from direct physical alteration of a wetland such as the placement of dredge or fill.

Direct Measure: A quantitative measure of an assessment model variable.

Functional Assessment: The process by which the capacity of a wetland to perform a function is measured. This approach measures capacity using an assessment model to determine a functional capacity index.

Functional Capacity: The rate or magnitude at which a wetland ecosystem performs a function. Functional capacity is dictated by characteristics of the wetland ecosystem and the surrounding landscape and interaction between the two.

Functional Capacity Index (FCI): An index of the capacity of a wetland to perform a function relative to other wetlands from a regional wetland subclass in a reference domain. Functional capacity indices are by definition scaled from 0.0 to 1.0. An index of 1.0 indicates that the wetland performs a function at the highest sustainable functional capacity, the level equivalent to a wetland under reference standard conditions in a reference domain. An index of 0.0 indicates the wetland does not perform the function at a measurable level and will not recover the capacity to perform the function through natural processes.

Highest sustainable functional capacity: The level of functional capacity achieved across the suite of functions by a wetland under reference standard conditions in a reference domain. This approach assumes that the highest sustainable functional capacity is achieved when a wetland ecosystem and the surrounding landscape are undisturbed.

Hydrogeomorphic Wetland Class: The highest level in the hydrogeomorphic wetland classification. There are five basic hydrogeomorphic wetland classes: depression, fringe, slope, riverine, and flat.

Hydrogeomorphic Unit: Hydrogeomorphic units are areas within a wetland assessment area that are relatively homogenous with respect to ecosystem scale characteristics such as microtopography, soil type, vegetative communities, or other factors that influence function. Hydrogeomorphic units may be the result of natural or anthropogenic processes. See **Partial Wetland Assessment Area.**

Indicator: Indicators are observable characteristics that correspond to identifiable variable conditions in a wetland or the surrounding landscape.

Indirect Measure: A qualitative measure of an assessment model variable that corresponds to an identifiable variable condition.

Indirect Impacts: Impacts resulting from a project that occur concurrently, or at some time in the future, away from the point of direct impact. For example, indirect impacts of a project on wildlife can result from an increase in the level of activity in adjacent, newly developed areas, even though the wetland is not physically altered by direct impacts.

In-kind Mitigation: Mitigation in which lost functional capacity is replaced in a wetland of the same regional wetland subclass.

Interflow: The lateral movement of water in the unsaturated zone during and immediately after a precipitation event. The water moving as interflow discharges directly into a stream or lake.

Jurisdictional Wetland: Areas that meet the soil, vegetation, and hydrologic criteria described in the "Corps of Engineers Wetlands Delineation Manual" (Environmental Laboratory 1987), or its successor.

Mitigation: Restoration or creation of a wetland to replace functional capacity that is lost as a result of project impacts.

Mitigation Plan: A plan for replacing lost functional capacity resulting from project impacts.

Mitigation Ratio: The ratio of the Functional Capacity Units lost in a Wetland Assessment Area to the Functional Capacity Units gained in a mitigation wetland.

Mitigation Wetland: A restored or created wetland that serves to replace functional capacity lost as a result of project impacts.

Model Variable: See **Assessment Model.**

O Horizon: A layer with more than 12 to 18 percent organic C (by weight; 50 percent by volume). Form of the organic material may be recognizable plant parts (Oi) such as leaves, needles, twigs, moss, etc.; partially decomposed plant debris (Oe); or totally decomposed organic material (Oa) such as muck.

Offsite Mitigation: Mitigation at a location physically separated from the site at which the original impacts occurred, possibly in another watershed.

Out-of-kind Mitigation: Mitigation in which lost function capacity is replaced in a wetland of a different regional wetland subclass.

Partial Wetland Assessment Area (PWAA): A portion of a Wetland Assessment Area (WAA) that is identified *a priori,* or while applying the assessment procedure, because it is relatively homogeneous and different from the rest of the WAA with respect to one or more model variables. The difference may occur naturally, or as a result of anthropogenic disturbance. Refer to **Hydrogeomorphic Unit**.

Project Alternative(s): Different ways in which a given project can be done. Alternatives may vary in terms of project location, design, method of construction, amount of fill required, and other ways.

Project Area: The area that encompasses all activities related to an ongoing or proposed project.

Project target: The level of functioning identified for a restoration or creation project. Conditions specified for the functioning are used to judge whether a project reaches the target and is developing toward site capacity.

Red Flag Features: Features of a wetland or the surrounding landscape to which special recognition or protection is assigned on the basis of objective criteria. The recognition or protection may occur at a Federal, state, regional, or local level, and may be official or unofficial.

Reference Domain: The geographic area from which reference wetlands are selected. A reference domain may or may not include the entire geographic area in which a regional wetland subclass occurs.

Reference Standards: Conditions exhibited by a group of reference wetlands that correspond to the highest level of functional capacity (highest sustainable level of functioning) across the suite of functions performed by the regional wetland subclass. The highest level of functional capacity is assigned an index value of 1.0 by definition.

Reference Wetlands: Wetland sites that encompass the variability of a regional wetland subclass in a reference domain. Reference wetlands are used to establish the range of conditions for construction and calibration of functional indices and establish reference standards.

Region: A geographic area that is relatively homogenous with respect to large-scale factors such as climate and geology that may influence how wetlands function.

Regional Wetland Subclass: Wetlands within a region that are similar based on hydrogeomorphic classification factors. More than one regional wetland subclass may be identified within each hydrogeomorphic wetland class depending on the diversity of wetlands in a region and assessment objectives.

Site Potential: The highest level of functioning possible given local constraints of disturbance history, land use, or other factors. Site capacity may be equal to or less than levels of functioning established by reference standards for the reference domain, and it may be equal to or less than the functional capacity of a wetland ecosystem.

Throughflow: The lateral movement of water in an unsaturated zone during and immediately after a precipitation event. The water from throughflow seeps out at the base of slopes and then flows across the ground surface as return flow, ultimately reaching a stream or lake. See **Interflow** for comparison.

Variable: An attribute or characteristic of a wetland ecosystem or the surrounding landscape that influences the capacity of the wetland to perform a function.

Variable Condition: The condition of a variable as determined through quantitative or qualitative measure.

Variable Index: A measure of how an assessment model variable in a wetland compares to the reference standards of a regional wetland subclass in a reference domain.

Wetland Ecosystem: In 404: ".......areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas" (Corps Regulation 33 CFR 328.3 and EPA Regulations 40 CFR 230.3). In a more general sense, wetland ecosystems are three-dimensional segments of the natural world where the presence of water, at or near the surface, creates conditions leading to the development of redoxomorphic soil conditions, and the presence of a flora and fauna adapted to the permanently or periodically flooded or saturated conditions.

Wetland Assessment Area (WAA): The wetland area to which results of an assessment are applied.

Wetland Banking: The process of creating a "bank" of created, enhanced, or restored wetland to serve at a future date as mitigation for project impacts.

Wetland Functions: The normal activities or actions that occur in wetland ecosystems, or simply, the things that wetlands do. Wetland functions result directly from the characteristics of a wetland ecosystem and the surrounding landscape, and their interaction.

Wetland Creation: The process of creating a wetland in a location where a wetland did not previously exist. Wetland creation is typically done for mitigation.

Wetland Enhancement: The process of increasing the capacity of a wetland to perform one or more functions. Wetland enhancement can increase functional capacity to levels greater than the highest sustainable functional capacity achieved under reference standard conditions, but usually at the expense of sustainability, or a reduction of functional capacity of other functions. Wetland enhancement is typically done for mitigation.

Wetland Restoration: The process of restoring wetland functions in a degraded wetland. Restoration is typically done as mitigation.

Wetland Values: A confusing term that mixes wetland ecological functions with personal or societal preferences. Has also been used in various economic contexts. This term should be avoided, if for no other reason, for lack of clarity.

Value of Wetland Function(s): The relative importance of wetland function, or functions, to an individual or group.

Appendix B
Summary Documentation of Functions and Variables

Summary of Functions

Function 1. Surface Water Storage

Variable	Function
V_{UPUSE}	Upland Land Use
$V_{EDGEUSE}$	Land Use of Outermost Wetland Zone
V_{WETUSE}	Land Use
V_{PORE}	Soil Pore Space of the parent material (C horizon)
$V_{HYDROMOD}$	Hydrologic Modification in the Wetland
V_{GEOMOD}	Geomorphic Modification in the Wetland

$$FCI = \left[\left(\frac{V_{UPUSE} + V_{EDGEUSE} + V_{WETUSE} + V_{PORE}}{4}\right) \times \left(\frac{V_{HYDROMOD} + V_{GEOMOD}}{2}\right)\right]^{1/2} \quad (1)$$

Function 2. Nutrient Cycling

Variable	Function
V_{WETUSE}	Land Use in the Wetland
$V_{EDGEUSE}$	Land Use in the Low Prairie zone surrounding Wetland
$V_{ORGDECOMP}$	Decomposition of Organic Matter
V_{PORE}	Soil Pore Space of the parent material (C horizon) material
V_{O+A_HORIZ}	Depth of O and A Soil Horizons
V_{SED}	Sediment Delivery

$$FCI = \left[\left(\frac{V_{WETUSE} + V_{EDGEUSE}}{2}\right)\times\left(\frac{V_{ORGDECOMP} + V_{O+A\_HORIZ} + V_{PORE} + V_{SED}}{4}\right)\right]^{1/2} \quad (6)$$

Function 3. Retention of Elements, Compounds, and Particulates

Variable	Function
V_{UPUSE}	Land Use in the upland surrounding the Wetland
$V_{EDGEUSE}$	Land Use in the Low Prairie zone surrounding Wetland
V_{WETUSE}	Land Use in the Wetland
V_{SED}	Sediment Delivery
V_{O+A_HORIZ}	Depth of O and A Soil Horizons
$V_{ORGDECOMP}$	Decomposition of Organic Matter

$$FCI = \left\{\left[\frac{(V_{UPUSE} + V_{EDGEUSE} + V_{WETUSE})}{3}\right]\times\left[\frac{(V_{SED} + V_{O+A\_HORIZ} + V_{ORGDECOMP})}{3}\right]\right\}^{1/2} \quad (11)$$

Function 4. Maintain Characteristic Plant Community

Variable	Function
V_{PDEN}	Wetland Plant Density
V_{NPDIV}	Percent Native Plant Diversity
V_{NPCOV}	Percent Coverage by Native Plants
$V_{\alpha DIV}$	Plant α-diversity across Wetland Zones
$V_{HYDROMOD}$	Hydrologic Modification in the Wetland
V_{GEOMOD}	Geomorphic Modification in the Wetland

$$FCI = \left[\left(\frac{V_{PDEN} + V_{NPDIV} + V_{NPCOV}}{3}\right)\times\left(\frac{V_{HYDROMOD} + V_{GEOMOD}}{2}\right)\times V_{\alpha DIV}\right]^{1/3} \quad (18)$$

Function 5. Maintain Characteristic Invertebrate Food Webs

Variable	Function
V_{WETUSE}	Land Use in the Wetland
$V_{EDGEUSE}$	Land Use in the Low Prairie zone surrounding Wetland
V_{O+A_HORIZ}	Depth of O and A Soil Horizons
V_{PDEN}	Wetland Plant Density
V_{SED}	Sediment Delivery
$V_{HYDROMOD}$	Hydrologic Modification in the Wetland
V_{GEOMOD}	Geomorphic Modification in the Wetland

$$FCI = \left\{ \left(\frac{V_{WETUSE} + V_{EDGEUSE}}{2} \right) \times \left[\frac{\left(V_{O+A\_HORIZ} + V_{PDEN} + V_{SED} \right)}{3} \right] \times V_{HYDROMOD} \times V_{GEOMOD} \right\}^{1/4} \tag{23}$$

Function 6. Maintain Characteristic Vertebrate Habitats

Variable	Function
V_{UPUSE}	Land Use in the upland surrounding the Wetland
$V_{EDGEUSE}$	Land Use in the Low Prairie zone surrounding Wetland
V_{WETUSE}	Land Use in the Wetland
V_{PDEN}	Wetland Plant Density
V_{NPDIV}	Percent Native Plant Diversity
V_{NPCOV}	Percent Coverage by Native Plants
$V_{\alpha DIV}$	Plant α-diversity across Wetland Zones
$V_{HYDROMOD}$	Hydrologic Modification in the Wetland
V_{GEOMOD}	Geomorphic Modification in the Wetland

$$FCI = \left[\left(\frac{V_{UPUSE} + V_{EDGEUSE} + V_{WETUSE}}{3} \right) \times \left(\frac{V_{PDEN} + V_{NPDIV} + V_{NPCOV} + V_{\alpha DIV}}{4} \right) \times V_{HYDROMOD} \times V_{GEOMOD} \right]^{1/4} \tag{30}$$

Function 7. Maintain Wetland Interspersion and Connectivity

Variable	Function
V_{UPUSE}	Land Use in the upland surrounding the Wetland
$V_{EDGEUSE}$	Land Use in the Low Prairie zone surrounding Wetland
V_{WETUSE}	Land Use in the Wetland
$V_{WETPROX}$	Distance of project wetland edge to nearest neighbors' Wetland edges
V_{WETDEN}	Density of Wetland
V_{GEOMOD}	Geomorphic Modification in the Wetland

$$FCI = \left[\left(\frac{V_{UPUSE} + V_{EDGEUSE} + V_{WETUSE}}{3} \right) \times \left(\frac{V_{WETDEN} + V_{WETPROX}}{2} \right) \times V_{GEOMOD} \right]^{1/3} \quad (32)$$

Summary of Variables

Land use variables

Upland Land Use (V_{UPUSE}). This variable is a function of the various land uses in the upland above the Low Prairie wetland zone. If the catchment boundary is extremely large or indistinct, then a perimeter of 100 m from the upper boundary of the Low Prairie is used as the functional upland zone of influence. The variable is scored based on the descriptive treatment and corresponding score in Table B1.

Table B1
Current Land Use Treatment in the Upland and Corresponding Variable Subindex Score

Current Land Use Treatment	Score
Commercial right-of-way or paved driveway	0.00
Private right-of-way or unpaved driveway	0.10
Heavy grazing by livestock	0.20
Annual crop production	0.20
Generalized soil disturbance	0.30
Residential or commercial lawn	0.40
Moderate grazing by livestock	0.50
Mowed and hayed, but uncultivated field	0.60
Light grazing by livestock	0.70
Conservation easement with planting	0.85
Fallow, no cultivation or livestock >2 years. but <10 years	0.90
Managed as undisturbed grassland >10 years, but <20 years	0.95
Managed as undisturbed grassland >20 years	1.00

V_{UPUSE} occurs in the following functions:

a. Function 1. Surface Water Storage

b. Function 3. Retention of Elements, Compounds, and Particulates

c. Function 6. Maintain Characteristic Vertebrate Habitats

d. Function 7. Maintain Wetland Interspersion and Connectivity

Land Use in the Wetland Edge ($V_{EDGEUSE}$). This variable is a function of the various land uses along the edge of the wetland. The wetland edge is generally categorized as the Low Prairie wetland zone (Stewart and Kantrud 1972). If the Low Prairie is indistinct, then $V_{EDGEUSE}$ is based on the area above the Wet Meadow wetland zone to a distance of 25 m. The variable $V_{EDGEUSE}$ is scored based on the descriptive treatment and corresponding score in Table B2.

Table B2
Current Land Use Treatment in the Low Prairie Wetland Zone and the Corresponding Variable Subindex Score

Land Use Treatment	Score
Current Use	
Heavy grazing by livestock	0.10
Annual crop production	0.10
Moderate grazing by livestock	0.40
Mowed and hayed, but uncultivated field	0.50
Light grazing by livestock	0.65
Conservation easement with planting	0.75
Fallow, no cultivation or livestock >2 years, but <10 years	0.90
Managed as undisturbed grassland >10 years, but <20 years	0.95
Managed as undisturbed grassland >20 years	1.00
Projected Use	
Fill with paving	0.00
Fill without paving	0.05
Partial fill	0.10

$V_{EDGEUSE}$ occurs in the following functions:

a. Function 1. Surface Water Storage

b. Function 2. Nutrient Cycling

c. Function 3. Retention of Elements, Compounds, and Particulates

d. Function 5. Maintain Characteristic Invertebrate Food Webs

e. Function 6. Maintain Characteristic Vertebrate Habitats

f. Function 7. Maintain Wetland Interspersion and Connectivity

Land Use in the Wetland (V_{WETUSE}). This variable is a function of the various land uses within the wetland. For this Guidebook, this area is categorized as the Wet Meadow, Shallow Marsh, and Deep Marsh wetland zones (Stewart and Kantrud 1972). There is considerable hydrogeomorphic variability among wetlands within this HGM class. Intermittent and temporary wetlands may possess only a Wet Meadow wetland zone to the center of the wetland, whereas semipermanent and permanent wetlands may possess a Wet Meadow, Shallow Marsh, and Deep Marsh. The variable V_{WETUSE} is scored based on the descriptive treatment and corresponding Variable Subindex Score in Table B3.

Table B3
Current Land Use Treatment in the Wet Meadow, Shallow Marsh, and Deep Marsh Wetland Zones and the Corresponding Variable Subindex Score

Land Use Treatment	Score
Current Use	
Heavy grazing by livestock	0.10
Dry Year crop production	0.20
Moderate grazing by livestock	0.30
Mowed and hayed, but uncultivated field	0.40
Light grazing by livestock	0.60
Fallow, no cultivation or livestock >2 years, but <10 years	0.80
Managed as undisturbed grassland >10 years, but <20 years	0.95
Managed as undisturbed grassland >20 years	1.00
Projected Use	
Fill with paving	0.00
Fill without paving	0.05
Partial fill	0.10

V_{WETUSE} occurs in the following functions:

a. Function 1. Surface Water Storage

b. Function 2. Nutrient Cycling

c. Function 3. Retention of Elements, Compounds, and Particulates

d. Function 5. Maintain Characteristic Invertebrate Food Webs

e. Function 6. Maintain Characteristic Vertebrate Habitats

f. Function 7. Maintain Wetland Interspersion and Connectivity

Hydrologic and geomorphic variables

Hydrologic Modification ($V_{HYDROMOD}$). This variable represents the change in duration of flooding within the wetland expressed as the number of weeks in the year that ponded water is present. This variable is based on the duration of flooding (i.e., water regime) in a typical water year since water storage can be significantly less following long-term drought or greatly extended following a long wet period. If possible, this variable should be evaluated directly by observation at the wetland site. If this is not possible, then indicators may be used to estimate the number of weeks of inundation during the year by observing soil and vegetation in the deepest part of the wetland basin. The least preferred estimate of duration would be based on NWI maps. Water regime within the wetland is based on the number of weeks of flooding and given a Cowardin et al. (1979) classification water regime score (Table B4).

Table B4
Duration of Wetland Flooding with Cowardin et al. (1979) Water Regime

Flooding Condition	Weeks Flooded	Water Regime
Temporarily flooded	1 - 4	A
Seasonally flooded	5 - 17	C
Semipermanently flooded	18 - 40	F
Intermittently exposed	41 - 51	G
Permanently flooded	52	H

Examples of direct hydrologic modification of the wetland include removal of water from the wetland for irrigation or supplementing the water budget by diverting runoff to the wetland. The latter is a common practice around transportation corridors. An example of indirect hydrologic modification is tiling or ditching the wetland to drain it for agriculture. The variable $V_{HYDROMOD}$ is scored by determining the number of weeks of the year the wetland floods under normative water budget conditions and projecting the change in duration in view of past or future projects. If the water regime is normative, then the current subindex score is 1.0. If there is a change in water regime, then the subindex score is determined by the matrix in Table B5, where the normative water regime is sited across the top row of the matrix table and the projected water regime is estimated and sited along the left of the matrix table. The intersection of normative and projected water regimes provides the subindex score.

Table B5
Matrix of Cowardin Water Regime in Which Subindex Scores Are Established by Determining the Normative and Projected Water Regimes

Altered Cowardin Water Regime \ Normative Cowardin Water Regime	A	C	F	G	H
A	1.0	0.7	0.5	0.2	0.1
C	0.7	1.0	0.7	0.5	0.2
F	0.5	0.7	1.0	0.7	0.5
G	0.2	0.5	0.7	1.0	0.7
H	0.1	0.2	0.5	0.7	1.0

$V_{HYDROMOD}$ occurs in the following functions:

a. Function 1. Surface Water Storage

b. Function 4. Maintain Characteristic Plant Community

c. Function 5. Maintain Characteristic Invertebrate Food Webs

d. Function 6. Maintain Characteristic Vertebrate Habitats

Geomorphic Modification (V_{GEOMOD}). This variable represents the anthropogenic modification of the geomorphic properties of the wetland through changes either to increase water storage or drain the wetland. Examples of geomorphic modification commonly practiced are tilling or ditching wetlands to remove water or dredging and excavating wetlands to increase water depth. Wetlands have been drained in the past most often so that the wetland can be cultivated and put into crop production. However, ditching or tilling may also have been done near home sites to drain the area for lawns or simply to reduce the standing water on the property.

The modification to the wetland is geomorphic in nature but directly effects hydrologic properties. Filling, dredging, tilling, and ditching are all modifications that change the fundamental character of the wetland. This variable is calculated as a function of change on a per-area basis and is linked to wetland zonation and vegetation communities (Table B6).

Table B6
Calculation Matrix of Subindex Scores Based on Unaltered and Altered Geomorphic Conditions by Wetland Zone

		Unaltered Wetland Zones			
		Low Prairie	Wet Meadow	Shallow Marsh	Deep Marsh
Altered Wetland Zones	Low Prairie	1.0	0.1	0.0	0.0
	Wet Meadow	0.8	1.0	0.8	0.5
	Shallow Marsh	0.2	0.8	1.0	0.8
	Deep Marsh	0.0	0.2	0.8	1.0

a. Function 1. Surface Water Storage

b. Function 4. Maintain Characteristic Plant Community

c. Function 5. Maintain Characteristic Invertebrate Food Webs

d. Function 6. Maintain Characteristic Vertebrate Habitats

e. Function 7. Maintain Wetland Interspersion and Connectivity

Soil variables

Soil Pore Space (V_{PORE}). This variable affects the ability of a wetland to dynamically store surface water as well as cycle elements within the wetland. Very fine textured soils containing a significant fraction of clay particles have a much slower rate of hydrologic conductivity than do coarse-textured soils. When the parent material soils that underlie a wetland result in the retention of water through the prevention of water loss to the groundwater, the wetland will have a greater potential to retain dynamically stored water. Soil pore space and the texture of the soil also play a significant role in the cycling of nutrients, both in the retention of nitrogen within the wetland waters and in the retention of phosphorus on clay particles. The variable V_{PORE} is scaled based on the descriptive soil texture of the C horizon in the Wet Meadow wetland zone and the corresponding score in Table B7.

Table B7
Soil Texture Table and Corresponding Texture Index Score

Soil Texture	Variable Subindex Score
Gravel	0.00
Sand	0.33
Loamy sand	0.42
Sandy loam	0.50
Sandy clay loam	0.58
Loam	0.67
Silt loam	0.75
Silt	0.83
Sandy clay	0.92
Clay loam	1.00
Silty clay loam	1.00
Silty clay	1.00
Clay	1.00

V_{PORE} occurs in the following functions:

a. Function 1. Surface Water Storage

b. Function 2. Nutrient Cycling

Decomposition of Organic Matter ($V_{ORGDECOMP}$). This variable represents the long-term storage of nutrients and is an index of the characteristic decomposer community of the wetland. The soil O horizon is composed largely of organic materials derived from dead plant matter, microbes, and to a lesser extent animals. The O horizon is the remains of various stages of decomposition; hence, it is both a nutrient store and nutrient recycling source for the wetland. Departures in the depth of the O horizon from reference standards are indicators of too little or too

much organic matter additions to the wetland or too fast or too slow a rate of decomposition.

The soil A horizon is a surface mineral soil characterized by the accumulation of humus. Humus is black, highly decomposed plant material. It is naturally colloidal and thus has a small particle size, large surface area, and net negative charge. Its ability to hold nutrients is greater than any other soil constituent. The depth and color of the A horizon are indexes of the ability of the soil to store nutrients for plant availability. Departures from reference standards are indicators of changes in long-term organic matter inputs. A thin, light-colored A horizon may be natural or may be the result of lowered productivity caused by management or losses of the A horizon due to erosion. An A horizon in the wetland having a thickness greater than reference standard is likely the result of accelerated erosion from adjacent uplands or unusually high levels of plant growth for an extended time period.

$V_{ORGDECOMP}$ is calculated as an Organic Matter Decomposition Factor based on the Munsell Soil Color Chart variables of chroma and hue (Table B8) of the A horizon in the Wet Meadow wetland zone and the depths (cm) of the A horizon and O horizon, also in the Wet Meadow.

The "Organic Matter Decomposition Factor" is calculated as

$$OMDF = \left(\frac{(ChromaA \times HueA \times DepthA)}{10} + DepthO \right) \tag{2}$$

Table B8
Hue Value and Corresponding Score Based on Munsell Color Chart

Munsell Hue	Score
2.5YR	17.5
5YR	15.0
7.5YR	12.5
10YR	10.0
2.5Y	7.5
5Y	5.0
N	2.5
GY G GB or B	0.0

The Variable Subindex Score for $V_{ORGDECOMP}$ is based on the relationship between the Organic Matter Decomposition Factor and the Variable Subindex Score illustrated in Figure B1.

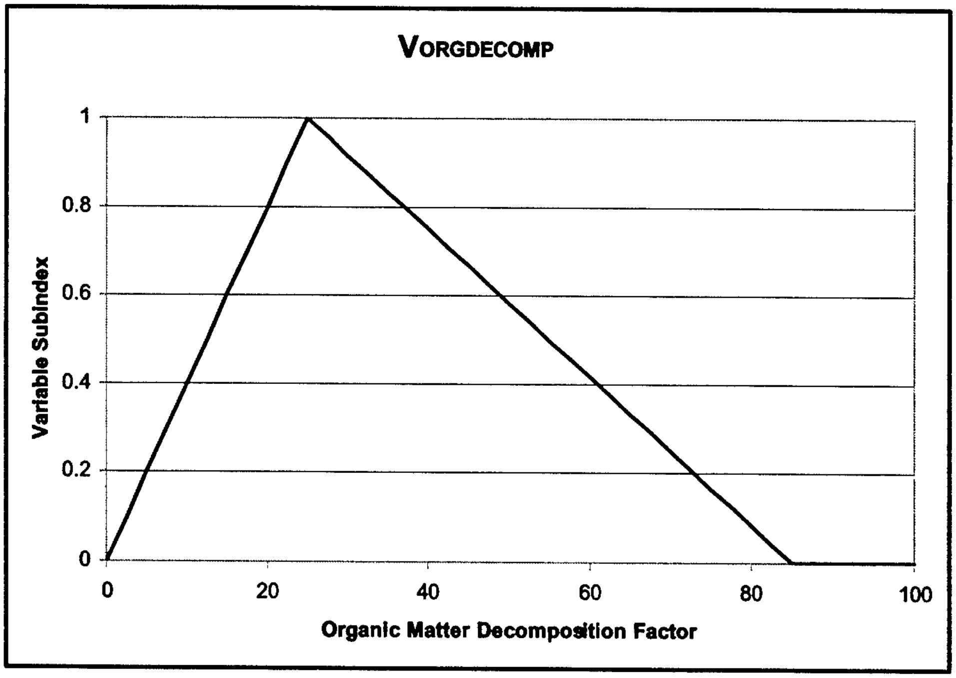

Figure B1. Correlation between OMDF and the Variable Subindex Score

$V_{ORGDECOMP}$ occurs in the following functions:

a. Function 2. Nutrient Cycling

b. Function 3. Retention of Elements, Compounds, and Particulates

Sediment Delivery (V_{SED}). This variable represents the potential amount of sediment entering a pothole wetland as a product of erosion from adjacent uplands. This is based on the RUSLE:

$$RUSLE\_Index = R \times K \times L \times S \times C \times P \tag{7}$$

where

R = rainfall-runoff erosivity factor, which for this Reference Domain is 1.0

K = soil erodibility factor of the adjacent upland based on Table B9

L = mean slope length, ft, of four transects taken from the catchment boundary to the outer edge of the Low Prairie wetland zone

S = mean slope, percent, of the four transects (h/l)

C = cover management factor

P = support practices factor

Table B9 Soil Texture, Geometric Mean Particle Size, and Corresponding K Erodibility Factor		
Soil Texture	**Log Mean Geometric Particle Diameter**	**K Erodibility Factor**
Silty clay	-1.2	0.041
Silt	-1.0	0.034
Silty clay loam	-0.9	0.03
Clay	-0.7	0.02
Silt loam	-0.6	0.018
Clay loam	-0.5	0.014
Loam	-0.4	0.01
Sandy clay	-0.3	0.009
Sandy clay loam	-0.2	0.007
Sandy loam	-0.2	0.006
Loamy sand	-0.1	0.003
Sand	0.0	0.001

In this procedure CP are combined and calculated as a single factor where:

$$CP = \frac{1}{\sqrt{\left[\frac{(V_{UPUSE} + V_{EDGEUSE})}{2}\right] \times V_{WETUSE}}} \tag{4}$$

The Variable Subindex Score for V_{SED} is based on the relationship between RUSLE and the Variable Subindex Score described by the equation:

$$V_{SED} \text{ Variable Subindex} = -0.1561 \times \ln(RUSLE) + 0.5243 \tag{5}$$

and illustrated in Figure B2.

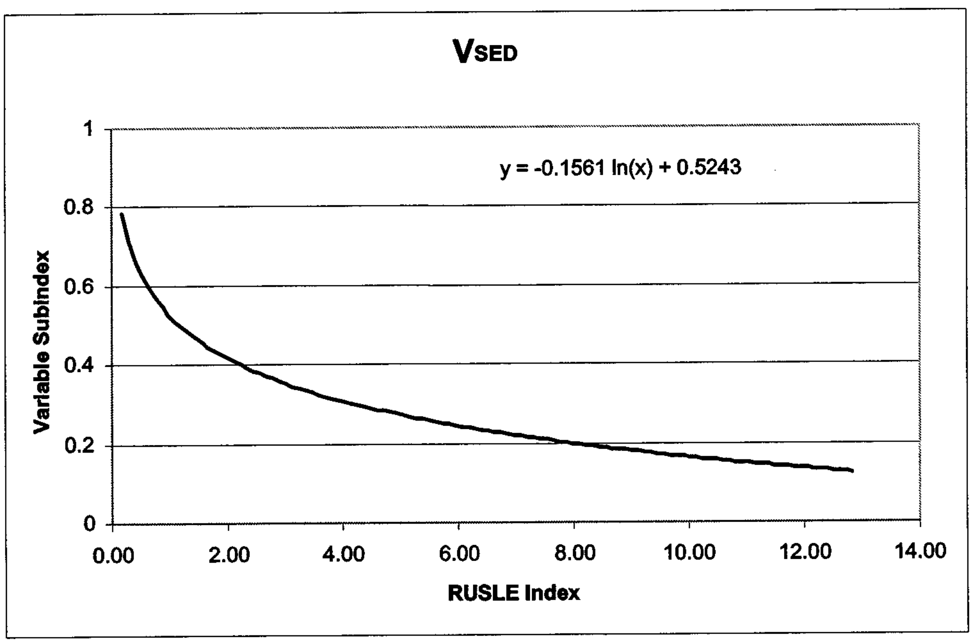

Figure B2. Relationship between RUSLE Index and the Variable Subindex Score

V_{SED} occurs in the following functions:

a. Function 2. Nutrient Cycling

b. Function 3. Retention of Elements, Compounds, and Particulates

c. Function 5. Maintain Characteristic Invertebrate Food Webs

Depth of the O and A Soil Horizons (V_{O+A_HORIZ}). This variable represents the weighted mean depth of the O and A soil horizons across each of the vegetation communities in the Low Prairie, Wet Meadow, Shallow Marsh, and Deep Marsh wetland zones. V_{O+A_HORIZ} is quantified by direct measurement of the O and A soil horizon depths from soil pits or from soil cores.

The Variable Subindex Score for V_{O+A_HORIZ} is based on the relationship between the added depths of the O horizon and the A horizon and the Variable Subindex Score illustrated in Figure B3.

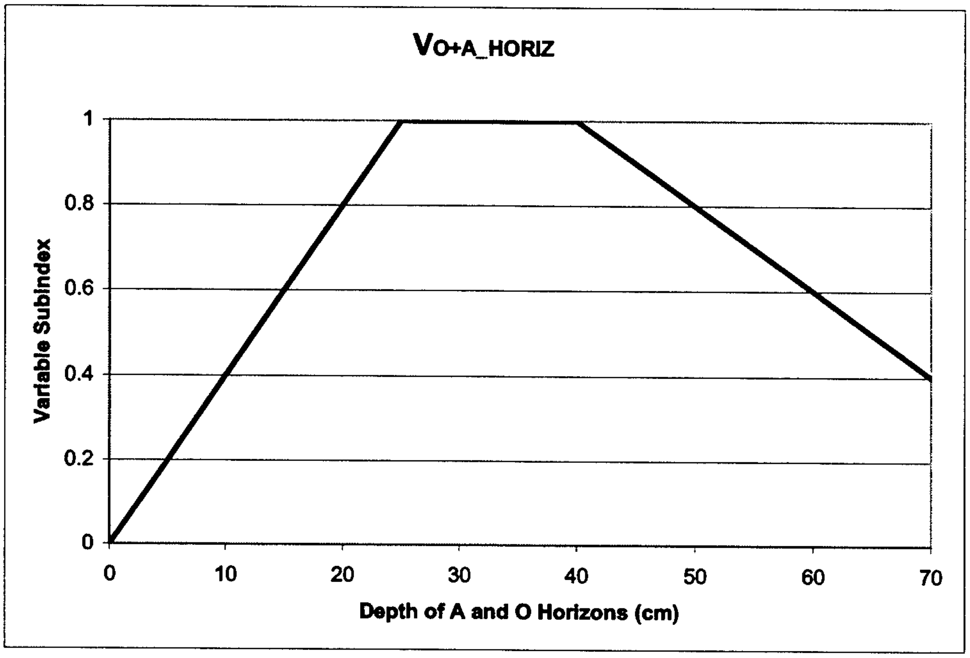

Figure B3. Relationship between O and A Horizon soil depths and the Variable Subindex Scores

V_{O+A_HORIZ} occurs in the following functions:

a. Function 2. Nutrient Cycling

b. Function 3. Retention of Elements, Compounds, and Particulates

c. Function 5. Maintain Characteristic Invertebrate Food Webs

Vegetation variables

Plant Density (V_{PDEN}). This variable represents the weighted mean density in stems/m^2 of plants within each of the vegetation communities in the Low Prairie, Wet Meadow, Shallow Marsh, and Deep Marsh. The vegetation in glacial pothole wetlands often appears as concentric rings around the wetland. These rings of vegetation generally coincide with hydrologic variation and have been described extensively in the literature, particularly regarding the Prairie Pothole Region (sensu Stewart and Kantrud 1972; Mitsch and Gosselink 1993).

The weighted mean plant density is determined by a series of vegetation plots taken within each vegetation community. The mean plant density from each vegetation community is multipled by the percent area of the whole wetland occupied by that community. The proportional plant densities of each vegetation community are added to obtain the Weighted Plant Density across the entire wetland.

The Variable Subindex Score for V_{PDEN} is based on the relationship between the Weighted Plant Density and the algorithm:

$$\text{Variable Subindex} = 0.1946 \ln (\boldsymbol{WPD}) - 0.7548 \tag{12}$$

illustrated in Figure B4.

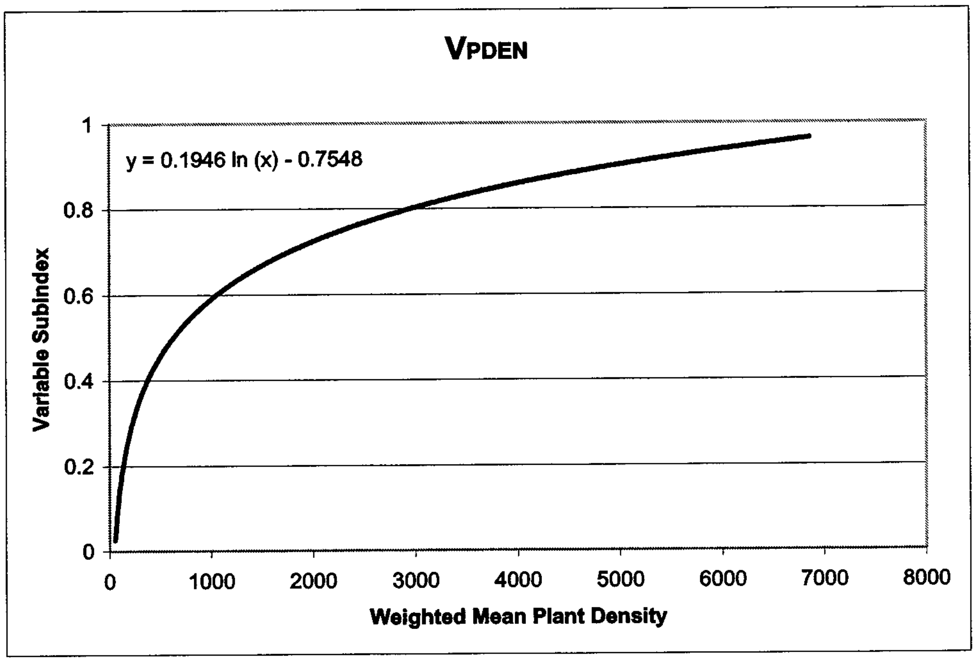

Figure B4. Correlation between Weighted Plant Density and the Variable Subindex Score

V_{PDEN} occurs in the following functions:

a. Function 4. Maintain Characteristic Plant Community

b. Function 5. Maintain Characteristic Invertebrate Food Webs

c. Function 6. Maintain Characteristic Vertebrate Habitats

Percent Native Plant Diversity (V_{NPDIV}). This variable represents the percent diversity of native plants within the wetland (i.e., below the Upland/Low Prairie boundary). Native plant diversity is important to maintaining ecosystem structure and function. Rates of processes (e.g., elemental cycling, detritus accumulation) depend on native plants as well as animal populations, which are adapted to native plants for food, cover, or nesting. Nonnative plants alter the natural physical structure that is characteristic of a native community and are often indicators of unnatural levels of disturbance. For example, canary grass (*Phalaris arundinacea*) is a nonnative that commonly occurs in the Wet Meadow habitat type of the Intermontane Glacial Potholes where an unnaturally high rate of sedimentation has been entering the wetland from upland land use, such as cultivation.

This variable is a comparison of the native to nonnative species complex. It requires obtaining a complete species list including a determination of native and nonnative status. V_{NPDIV} is measured as the weighted average percent native species across all vegetation communities in the Low Prairie, Wet Meadow, Shallow Marsh, and Deep Marsh. This value is then scaled to give the Variable Subindex Score based on the following regression equation and illustrated in Figure B5:

$$\text{Variable Subindex} = 0.0092\,(\%NS) + 0.0768 \qquad (13)$$

V_{NPDIV} occurs in the following functions:

a. Function 4. Maintain Characteristic Plant Community

b. Function 6. Maintain Characteristic Vertebrate Habitats

Percent Coverage by Native Plants (V_{NPCOV}). This variable represents the weighted mean percent coverage of native plants within each of the vegetation communities of the wetland. Similar in concept and calculation to the variable V_{PDEN}, V_{NPCOV} is a measure of the percent coverage by native plants across the wetland. This variable is quantified by estimating the percent coverage within each community by native plants.

Native plant coverage is important to maintaining ecosystem structure and function. Rates of processes (e.g., elemental cycling, detritus accumulation) depend on native plants, as well as animal populations, which are adapted to native plants for food, cover, and nesting. Nonnative plants alter the natural physical structure that is characteristic of a native community and are often indicators of unnatural levels of disturbance.

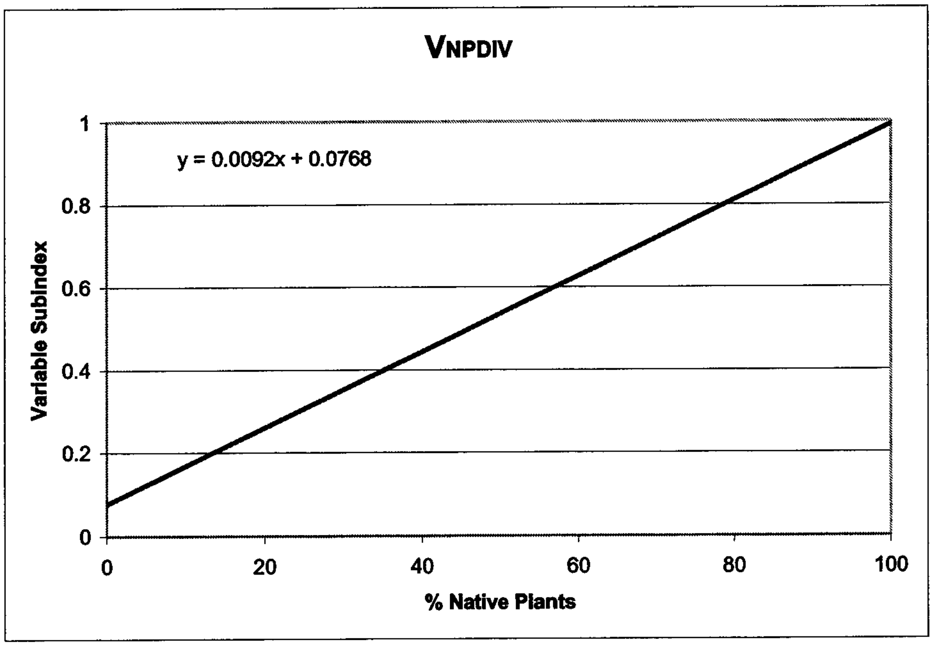

Figure B5. Correlation between Percent Native Plants and the Variable Subindex Scores

The correlation between percent native plant coverage and the variable subindex among the reference wetlands is described by the following regression equation and illustrated in Figure B6:

$$\text{Variable Subindex} = y = 0.0076\,(\boldsymbol{WNPC}) + 0.2166 \qquad (14)$$

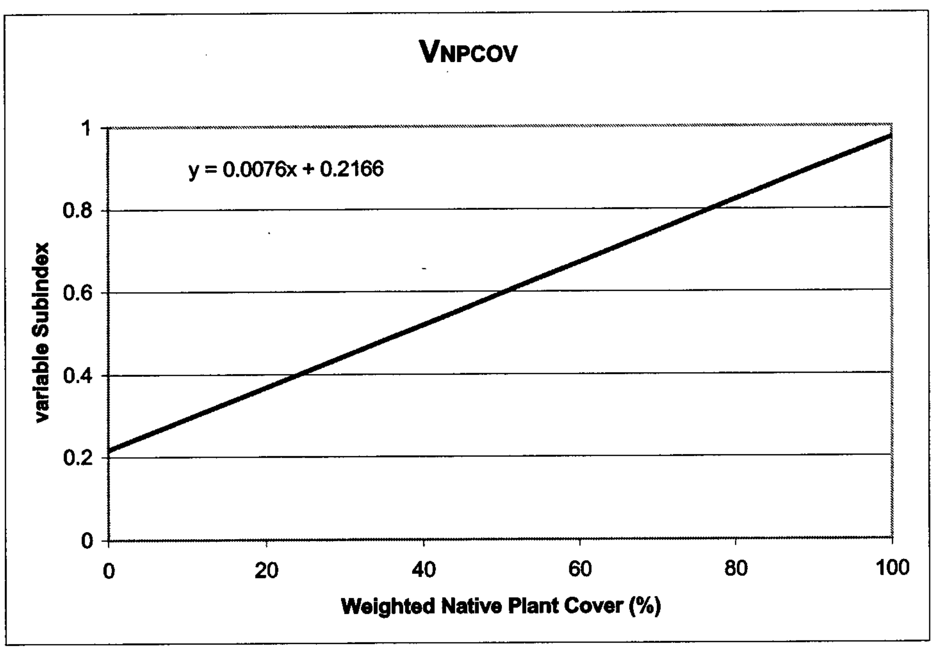

Figure B6. Correlation between percent Native Plant Cover and the Variable Subindex Score

V_{NPCOV} occurs in the following functions:

a. Function 4. Maintain Characteristic Plant Community

b. Function 6. Maintain Characteristic Vertebrate Habitats

Plant α-diversity across Wetland Zones ($V_{\alpha DIV}$). This variable is a measure of the α-diversity of plant species across each vegetation community and wetland zone. Reference standard wetlands in the Intermontane Glacial Pothole reference domain have numerous species distributed across multiple habitat types. Typically, the Low Prairie has the greatest species diversity, followed by the Wet Meadow and then the Shallow and Deep Marshes. For analyses on these pothole wetlands, this variable is measured as the weighted average Variable Subindex Score, where the Low Prairie, Wet Meadow, and the two Marsh types of wetland zones have independent regression relationships.

The correlation between α-diversity and the variable subindex for the three wetland zones and across the reference wetlands is described by the following three regression equations and illustrated in Figure B7:

$$\text{Low Prairie Subindex} = 0.2431 \times \ln(\alpha\text{-diversity}) + 0.6483 \quad (15)$$

$$\text{Wet Meadow Subindex} = 0.2087 \times \ln(\alpha\text{-diversity}) + 0.5943 \quad (16)$$

$$\text{Shallow and Deep Marsh} = 0.203 \times \ln(\alpha\text{-diversity}) + 0.4984 \quad (17)$$

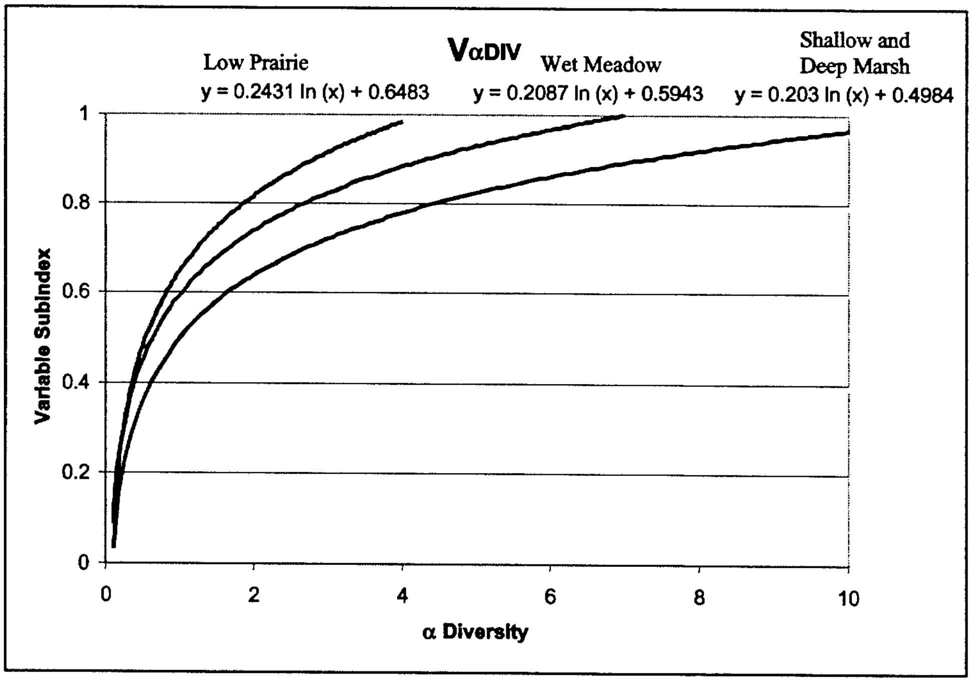

Figure B7. Correlation between α-diversity and the Variable Subindex Score

$V_{\alpha DIV}$ occurs in the following functions:

a. Function 4. Maintain Characteristic Plant Community

b. Function 6. Maintain Characteristic Vertebrate Habitats

Landscape variables

Nearest Neighbor Distances ($V_{WETPROX}$). This variable is a measure of the proximity of similar wetlands (i.e., wetlands of the same HGM class) to the wetland being assessed. This is a critical landscape variable that affects the ability of species to move from one wetland to another. The variable is determined as the mean distance (m) between the assessment wetland and its closest five wetlands:

$$MeanDist = \left[\frac{(Dist1) + (Dist2) + (Dist3) + (Dist4) + (Dist5)}{5} \right] \tag{31}$$

This variable achieves a maximum score of 1 as the mean distance between wetlands approaches <100 m. Likewise, the Variable Subindex Score equals zero when the mean distance is $\geq$ 500 m. The Variable Subindex Score for $V_{WETPROX}$ is based on the relationship between the mean distance of the nearest five neighbors to the assessment wetland and the Variable Subindex Score illustrated in Figure B8.

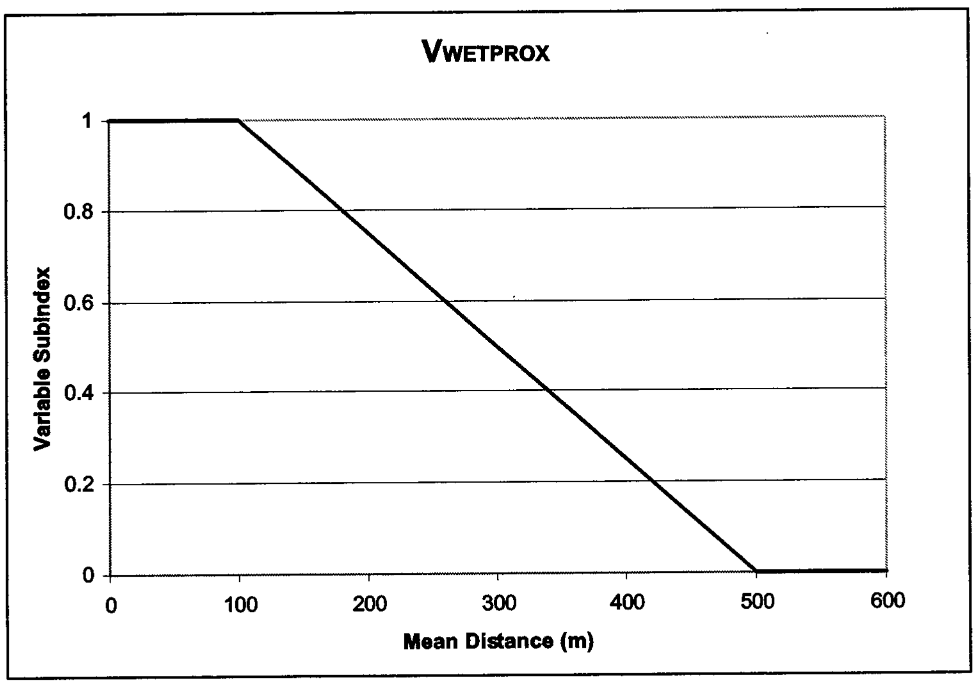

Figure B8. Relationship between Mean Distance between wetlands and the Variable Subindex Score

$V_{WETPROX}$ occurs in Function 7, Maintain Wetland Interspersion and Connectivity.

Density of Wetlands (V_{WETDEN}). This variable is a measure of the density of wetlands as a percentage of the total area within an 800-m (0.5-mile) radius around the assessment wetland. Glacial potholes function within a larger landscape. Plant propagules, invertebrates, and vertebrates are dependent on movement of seeds or individuals from one wetland to another. For example, migratory waterfowl and wide-ranging large mammals have different home range requirements from those of small mammals and herptiles. This variable is intended to capture the relative affinity of wetland density. Like $V_{WETPROX}$, this is a critical landscape variable that estimates the density of wetland habitat within an area that is relatively easy to access by large vertebrates and easily colonized by small vertebrates.

This variable may be estimated using GIS and air photos or NWI maps, or the source maps and photos may be interpreted by other less sophisticated methods. Regardless of the mechanical approach taken, the objective is to estimate the overall percent coverage of wetland habitat within a ~800-m (0.5-mile) radius around the assessment wetland. This variable is scaled after the reference wetland areas of Ninepipe and the Ovando area pothole wetlands and is described by the relationship illustrated in Figure B9.

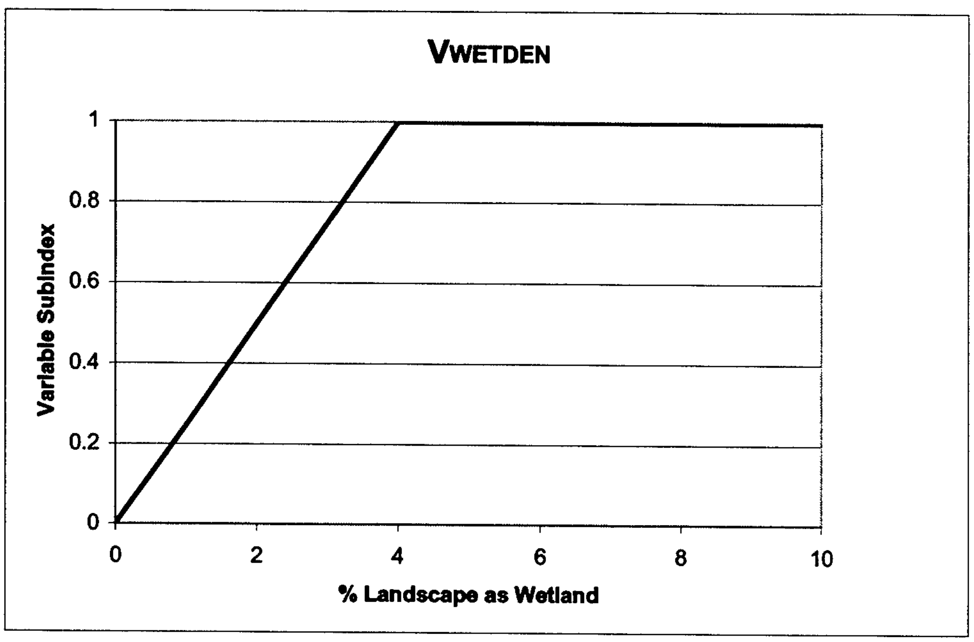

Figure B9. The relationship between the percentage of the landscape within an 800-m (0.5-mile) radius that is covered by wetland and the Variable Subindex Score

$V_{WETPROX}$ occurs in Function 7, Maintain Wetland Interspersion and Connectivity.

Appendix C
Field Data Sheets

This appendix contains the Field Data Sheets that prompt the one conducting the wetland functional assessment for specific information and data commensurate with the Assessment Protocols from Chapter 5.

The data sheets Landscape and Land Use Data, Hydrologic and Geomorphic Data, Soil Data, and Vegetation and Habitat Data also appear in an electronic form with the WINDOWS-compatible program <IMPPotholeFCI.xls> at *http://www.wes.army.mil/el/wetlands/hgmhp.html.*

Intermontane Prairie Pothole Wetlands
Northern Rocky Mountains

Landscape and Land Use Data

Project Name: ______________________________ Date: ________________
Location USGS Quad Map Name: ____
Location Latitude: _________________________ Longitude: ________________
Assessment Team: ____

Wetland Density in the Landscape:
Percent of landscape within 800-m (alternate: 0.5-mile) radius of Project Wetland centroid that is wetland.

__________________ %

Project Wetland
Area of Wetland Zones:

Wetland Zone	**Area (m^2)**
Low Prairie	
Wet Meadow	
Shallow Marsh	
Deep Marsh	
Total	

Characterization of Upland Areas and Land Use:

Upland Vegetation Community	**Estimated % Area**	**Land Use Treatment Score**
UVC#1		
UVC#2		
UVC#3		
UVC#4		
UVC#5		

(Continued)

Landscape and Land Use Data (Concluded)

Project Name: ______________________________ Date: ____________________

Wetland Vegetation Communities—Zone, Area and Land Use Treatments

Wetland Vegetation Community	Wetland Zone (LP, WM, SM, DM)	Area (m^2)	Land Use Treatment Score
VC#1			
VC#2			
VC#3			
VC#4			
VC#5			
VC#6			
VC#7			
VC#8			
VC#9			
VC#10			
VC#11			
VC#12			
VC#13			
VC#14			
VC#15			
VC#16			
VC#17			
VC#18			
VC#19			
VC#20			

Intermontane Prairie Pothole Wetlands
Northern Rocky Mountains

Landscape and Geomorphic Data

Project Name: ______________________ Date: ______________

Distance to Nearest Neighbors:

Nearest Neighbor	Distance (m)
#1	
#2	
#3	
#4	
#5	
AVERAGE	

Catchment Geomorphic Characteristics:

Catchment Transect	Change in Elevation (m)	Transect Length (m)
Transect a		
Transect b		
Transect c		
Transect d		

Intermontane Prairie Pothole Wetlands
Northern Rocky Mountains

Hydrologic and Geomorphic Data

Project Name: ______________________ Date: ______________
Location USGS Quad Map Name: ______________________
Location Latitude: ________________ Longitude: ________________
Assessment Team: ______________________

Duration of Wetland Flooding:

Normative Cowardin Water Regime _____ Altered Cowardin Water Regime _______

($V_{HYDROMOD}$) Subindex Score ____________

Flooding Condition	Weeks Flooded	Water Regime
Temporarily flooded	1 - 4	A
Seasonally flooded	5 - 17	C
Semipermanently flooded	18 - 40	F
Intermittently exposed	41 - 51	G
Permanently flooded	52	H

Normative Cowardin Water Regime (columns); Altered Cowardin Water Regime (rows)

	A	C	F	G	H
A	1.0	0.7	0.5	0.2	0.1
C	0.7	1.0	0.7	0.5	0.2
F	0.5	0.7	1.0	0.7	0.5
G	0.2	0.5	0.7	1.0	0.7
H	0.1	0.2	0.5	0.7	1.0

(Continued)

Hydrologic and Geomorphic Data (Concluded)

Project Name: ______________________ Date: ______________

Project Wetland
Area of Wetland Zones and V_{GEOMOD} Subindex Scores:

Wetland Zone	Area (m^2)	Subindex Score
Low Prairie		
Wet Meadow		
Shallow Marsh		
Deep Marsh		

Unaltered Wetland Zones

Altered Wetland Zones	Low Prairie	Wet Meadow	Shallow Marsh	Deep Marsh
Low Prairie	1.0	0.1	0.0	0.0
Wet Meadow	0.8	1.0	0.8	0.5
Shallow Marsh	0.2	0.8	1.0	0.8
Deep Marsh	0.0	0.2	0.8	1.0

(V_{GEOMOD}) Subindex Score __________

Intermontane Prairie Pothole Wetlands
Northern Rocky Mountains

Soil Data

Project Name: ____________________ Date: ____________
Location USGS Quad Map Name: ______________________________
Location Latitude: ________________ Longitude: ________________
Assessment Team: ______________________________________

Upland:

Texture of A Horizon	________
Soil Texture Subindex Score	________
K-erodibility factor	________

Low Prairie:

Depth of O Horizon (cm)	________
Depth of A Horizon (cm)	________

Wet Meadow:

Depth of O Horizon (cm)	________
Depth of A Horizon (cm)	________
A Horizon – Hue Subindex Score	________
Chroma of A Horizon (from Munsell Color Chart)	________
Texture of C Horizon	________
Texture of C Horizon Index Score	________

Shallow Marsh:

Depth of O Horizon (cm)	________
Depth of A Horizon (cm)	________

Deep Marsh:

Depth of O Horizon (cm)	________
Depth of A Horizon (cm)	________

(Sheet 1 of 3)

Soil Data (Continued)

Project Name: ______________________________ Date: ____________________

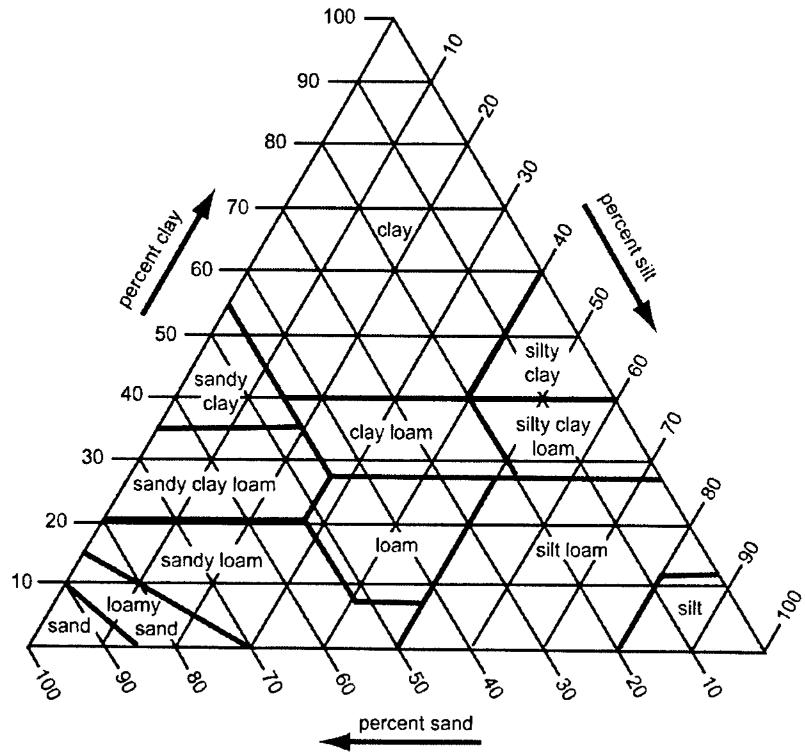

Chart showing the percentages of clay, silt, and sand in the basic soil textural classes and the corresponding soil textual name.

Soil texture, geometric mean particle size, and corresponding K-erodibility factor.

Soil Texture	Log Mean Geometric Particle Diameter	K-erodibility factor
Silty clay	-1.2	0.041
Silt	-1.0	0.034
Silty clay loam	-0.9	0.03
Clay	-0.7	0.02
Silt loam	-0.6	0.018
Clay loam	-0.5	0.014
Loam	-0.4	0.01
Sandy clay	-0.3	0.009
Sandy clay loam	-0.2	0.007
Sandy loam	-0.2	0.006
Loamy sand	-0.1	0.003
Sand	0.0	0.001

(Sheet 2 of 3)

Soil Data (Concluded)

Project Name: ______________________________ Date: ____________________

Soil texture table and corresponding Variable Subindex Score.

Soil Texture	Variable Subindex Score
Gravel	0.00
Sand	0.33
Loamy sand	0.42
Sandy loam	0.50
Sandy clay loam	0.58
Loam	0.67
Silt loam	0.75
Silt	0.83
Sandy clay	0.92
Clay loam	1.00
Silty clay loam	1.00
Silty clay	1.00
Clay	1.00

Hue value and corresponding score based on Munsell Color Chart.

Munsell Hue	Score
2.5YR	17.5
5YR	15.0
7.5YR	12.5
10YR	10.0
2.5Y	7.5
5Y	5.0
N	2.5
GY G GB or B	0.0

(Sheet 3 of 3)

Intermontane Prairie Pothole Wetlands
Northern Rocky Mountains

Vegetation and Habitat Data

Project Name: ______________________ Date: ______________
Location USGS Quad Map Name: ______________________________
Location Latitude: __________________ Longitude: __________________
Assessment Team: ______________________________________

Vegetation Community # ____________ **Wetland Zone:** __________
Plot #1:
Stem Density (stems/m^2) ________

Species	**Native/Exotic (N/E)**	**% Coverage**

Plot #2:
Stem Density (stems/m^2) ________

Species	**Native/Exotic (N/E)**	**% Coverage**

Plot #3:
Stem Density (stems/m^2) ________

Species	**Native/Exotic (N/E)**	**% Coverage**

Intermontane Prairie Pothole Wetlands
Northern Rocky Mountains
Physical Site Characterization Map

Project Name: ______________ Date: ______________ USGS Quad Map Name: ______________
Location: Latitude: ______________ Longitude: ______________ Assessment Team: ______________

Veg Communities

Low Prairie	#1 ________	#2 ________	#3 ________	#4 ________
Wet Meadow	#1 ________	#2 ________	#3 ________	#4 ________
Shallow Marsh	#1 ________	#2 ________	#3 ________	#4 ________
Deep Marsh	#1 ________	#2 ________	#3 ________	#4 ________

Appendix D
Reference Wetland Data Set

Depressional Physical Characterization Variables

Reference Pothole	Water Duration	Hydrographic Modification	Water Volume	Surface Area
n1	15	4	204	470
n2	12	4	194	609
n3	52	4	3763	7992
n4	8	4	137	848
n5	32	4	325	1011
n6	32	4	376	1770
n7	20	4	87	811
n8	15	4	279	1405
b9	32	4	1255	2953
b10	40	4	1633	3375
b11	32	4	159	458
b12	32	4	74	386
b13	40	4	531	1038
b14	7.5	4	50	181
b15	2	4	383	895
b16	52	4	293	528
s17	10	2	1661	5518
s18	32	3	1827	7679
s19	15	3	801	3013
l20	50	4	4798	7394

Soil Characterization Variables

Reference Pothole	Detritus Accum	Soil Sedimt	Soil Organic Mat	Soil Texture
n1	13.6	1.69	3143	2
n2	5.6	1.99	3157	3
n3	16.6	1.60	2262	2
n4	3.8	1.69	2454	4
n5	11.5	1.56	3508	1
n6	6.9	1.56	3150	1
n7	4.0	1.56	2560	1
n8	6.6	1.85	2320	2
b9	3.5	1.25	3230	3
b10	5.2	1.18	3681	3
b11	0.0	1.25	3800	4
b12	0.0	1.25	6664	2
b13	1.6	1.25	4152	4
b14	0.0	1.25	1950	2
b15	0.0	1.25	490	3
b16	5.8	1.32	2577	4
s17	0.0	3.97	2135	2
s18	0.0	2.48	1825	2
s19	0.0	2.37	1680	2
l20	10.1	7.40	12754	4

Plant Characterization Variables

Reference Pothole	Plant Density	Native Plant Diversity	Native Plant Coverage
n1	431.2	40.0	4.3
n2	278.0	0.0	0.0
n3	701.1	62.5	22.4
n4	844.2	50.0	72.4
n5	1079.6	60.0	46.7
n6	2319.9	50.0	80.1
n7	5030.0	50.0	68.0
n8	4248.7	60.0	82.7
b9	2732.2	93.8	92.1
b10	2169.2	93.8	94.2
b11	6863.3	100.0	96.0
b12	4948.0	100.0	100.0
b13	5497.5	85.7	92.1
b14	3354.2	100.0	97.3
b15	2178.0	85.7	70.6
b16	924.9	77.8	73.2
s17	55.3	42.9	0.0
s18	554.7	25.0	14.6
s19	1192.4	25.0	0.2
l20	1267.0	68.4	61.6

	Landuse Variables			Landscape Variables	
Reference Pothole	Upland Landuse	Wetland Edge Landuse	Wetland Landuse	Wetland Density	Wetland Proximity
n1	0.5	0.6	0.6	11.0	47.0
n2	0.2	0.6	0.6	10.2	33.1
n3	0.6	0.6	0.6	10.3	21.6
n4	0.5	0.6	0.6	9.6	16.8
n5	0.6	0.6	0.6	9.6	34.6
n6	0.6	0.6	0.6	9.9	29.8
n7	0.6	0.6	0.6	8.8	24.0
n8	0.3	0.4	0.8	9.6	36.0
b9	0.8	0.8	0.8	5.4	47.0
b10	0.9	0.9	0.9	5.0	67.7
b11	0.8	0.8	0.8	4.7	75.8
b12	0.8	0.8	0.8	4.5	82.6
b13	0.8	0.8	0.8	4.8	73.0
b14	0.8	0.8	0.8	4.7	68.6
b15	0.8	0.8	0.8	4.2	47.0
b16	0.8	0.7	0.8	3.7	122.4
s17	0.3	0.2	0.3	2.8	69.1
s18	0.5	0.2	0.5	2.6	51.8
s19	0.6	0.2	0.5	2.8	80.2
l20	0.1	0.1	0.2	4.6	112.8

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14. ABSTRACT
The Hydrogeomorphic (HGM) Approach to Wetland Functional Assessment is a collection of concepts and methods that are used to develop and apply functional indices to the assessment of wetlands. The HGM Approach includes four integral components: (a) HGM Classification, (b) Reference Wetlands, (c) Assessment Models and Functional Indices, and (d) Application Protocols. The four components of the HGM Approach are integrated into a Regional, Subclass-specific Guidebook such as this document. In the Development Phase of the HGM Approach, research scientists and regulatory managers work cooperatively to select a list of functions and indicators of function that will represent the functional range of variation among wetlands of the subclass and region. An Assessment Team (A-Team) gathers data from an array wetlands that represent that range of variation and establish a data set of Reference Wetlands. The functional models and data are combined along with field protocols and methods for analysis to formulate the Regional Guidebook. The end users then employ the Regional Guidebook during the Application Phase to conduct HGM functional assessments on project wetlands.

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